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Why design students need to be taught more about human vision - a pedagogical case

Abstract

Design education has traditionally taught techniques and approaches to practice, which students can use to create impact in their work, and be effective in communicating ideas. Those techniques and approaches have been developed over centuries of practice, much of it intuitive in nature, involving experience, experimentation and a blend of skills that do not rely on detailed scientific knowledge about vision in order to produce stunning results. In recent decades, designers have also been open to new technologies which have impacted hugely on the processes and speed with which we design.

The problem is that recent advances in other fields such as vision science have now opened up possibilities for a whole new range of techniques and approaches to design, but educationalists around the world still seem to be largely unaware of the importance of these advances on the future of design education.

The approach of this paper is firstly to introduce to an audience of designers, some of the more important vision science findings, effectively the 'rules and programmes' by which human beings see things. Those findings are then mapped onto design practices through a framework which suggests where the theoretical links and connections are between the two fields.

The paper then goes on to describe the research carried out, and the digital tools developed by which we can analyse and see for ourselves how vision science principles affect the way we see images. A multimedia based approach has been used to demonstrate how even complex vision concepts can be presented in ways that make them accessible for use by creative individuals.

The authors' intentions are however not just to stop at understanding the processes by which the human brain interprets signals sent by the eye. The main thrust of this research has been to complete the loop, by making such understanding accessible to arts-minded individuals through examples, demonstrations of principle and the creation of digital tools that act as interfaces between science and art.

This paper presents the case for a higher profile of vision based understanding in art and design education, arguing that such knowledge can increasingly be regarded as a source of creativity.

Keywords: vision, design, multimedia, education, theory

Introduction

This paper introduces the rapidly advancing field of vision science, describing its growing relevance to the practice of design, and therefore to design education. In order to develop foundations of vision science understanding in the minds of future designers, the paper considers pedagogies for embedding this knowledge. An interactive multimedia based form of experiential learning has been developed by the authors to teach aspects of vision science to designers, and the approach is described together with examples. It is a mental modelling approach to understanding, with its origins in the constructivist ideas of John Dewey and Jean Piaget that utilises a 'rich environment for active learning' (Malins, et al 2007:2)

Interactive experiential engagement adds an essential affective element to the learning process. 'The affective domain, which is often overlooked in pedagogy … is one of the distinguishing marks of experiential learning' (Gentry, 1990:10 as reported by Hansen, 2005:158). Care has been taken to ensure that the content and appropriate educational thinking drives the multimedia and not the other way round. 'The need for suitable educational frameworks in the use of multimedia technology…has been emphasized by many researchers.' (Adams, et al 1996 as reported by Kinshuk & Patel, 2003:55)

Designing in sympathy with the way the human brain processes vision is a field of knowledge we are calling 'vision-directed design'. We argue that this should become an area of curriculum development in design education, and we propose a framework for mapping design processes and concepts to vision science processes, so that designers can better understand where the science is able to support their creative outcomes. Vision-directed design is not intended to replace existing design practices, but rather to support them.

The need for vision science in design education

Most designers are very visually aware and trained to communicate ideas to an audience through various forms of visual media. It therefore seems strange that a basic understanding of how that audience physically sees things is not normally a core part of their training. 'Art and cognition have always stood as two convex mirrors each reflecting and amplifying the other. Yet, surprisingly, in spite of monumental recent developments in both aesthetics and cognition, the connection between the two disciplines has not been studied systematically.' (Solso 1994:preface xiii)

A gap exists between visual science and visual art that can be addressed in design education. David Hubel, professor of Neurobiology at Harvard and Nobel Prize winner, said 'Given two hours, I could make anyone with a good high school education fully aware of the main accomplishments in the last half century of visual science…Given how easy it is to convey these ideas, it seems unfortunate that people in general and artists in particular should be so isolated from them.' (Livingstone 2002:8).

What you 'see' is not always what you get

Most design education works on the assumption that the target audience will initially see the same physical thing, even if it is then interpreted in different ways, but this is not completely true. 'We think it is the world itself we see in our "mind's eye" rather than a coded picture of it (Nichols, 1981:11-12). Zeki (1999:68) 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'

By way of example, a simple visual detection task under scientific conditions can demonstrate that it is the brain which constructs an image and not what we take to be the 'reality' of the world. In the experiment, the subject is shown a series of images and has to say when they see a particular pattern. The researcher makes the pattern progressively more difficult to see, and increasingly the subject gets it wrong. Sometimes the pattern is in front of them but they report seeing nothing, while other times they report seeing a pattern when there is not even one there.

If the brain is scanned while carrying out this test using functional magnetic resonance imaging (fMRI), then on the occasions when the subject reports seeing a pattern that is not actually there, the brain activity behaves just as it did when the pattern was in front of them. This 'demonstrates that it doesn't matter what physical pattern is presented to a person, what does matter is what is happening in their brain' (Baars & Gage, 2007:173). This principle, which has been emphasised by numerous scientific authors writing about vision and art including Solso 1994; Zeki 1999; Livingstone 2002 and others, is very important for designers to understand. It means that the image that we 'see' is in fact, entirely a creation of the brain, according to its own rules and programmes, interpreted from patterns of light.

Implications of vision science for designers

The evidence from visual research is increasingly revealing an underlying potential for designers to persuade the brain to see things that are not there, to miss things that are actually present, or to objectively create impact and emphasis. Consider this: What if our knowledge of the way the brain interprets signals from the eye, allowed us to amplify or manipulate particular aspects of human perception? As designers, this would surely give us far more effective control over cognitive and emotional responses in the target audience. It is therefore something that design educators should be considering more seriously.

Whilst aesthetic visual awareness has always been at the heart of art and design, it is important to note that 'vision-directed design' as a proactive practical concept is still at the very early stages. However, with a growing understanding across the visual sciences, this is starting to change. The fifty or more demonstrations of principle, practical examples, and tools that our research has developed, provide insights into some of the possibilities ahead.

Current experiential learning in design education

A great deal of design education is already experiential in nature. Design students are expected to actively experiment in order to build skills and concrete experience. They are regularly given the opportunity to have their work critiqued by tutors and their peers which reinforces the importance of observing and reflecting on it. Feedback allows them to conceptualise new developments for their work which they can then experiment with. This becomes an iterative process and a classic Kolb experiential learning cycle (Kolb, 1984). Kolbs approach has its critics, (Garner, Race et al as reported by Atherton, 2005) but the model works well for the kind of learning we propose.

Multimedia experiential learning

Nicholas Negroponte, of the Media Lab at MIT said "multimedia is the slayer of boredom, the seducer of the senses and the arch nemesis of the 'been there, done that' attitude" (Jameson 1998:6). In the past there has been much hype about the potential of multimedia which has generated cynicism, but used properly, multimedia can achieve results that are difficult to achieve through most other forms of classroom interaction.

The common pitfall with multimedia is to throw in as many 'bells and whistles' as possible….just because you can! To avoid this pitfall, the focus using multimedia should be on the instructional intent and the best way of achieving deep learning. Certainly 'it should not be assumed that simply adding a visual or audio component will enhance learning' (Ellis, 2001 as reported by Kinshuk & Patel, 2003:56). Similarly, Rogers et al (1995) point out that 'just the collection and integration of multimedia objects in a system does not guarantee adequate learning' (Kinshuk & Patel, 2003:56).

In terms of experiential learning generally, the most common activities which tutors implement tend to be quite familiar and obvious ones falling into two types of e-learning : *assimilative*, such as reading an online article or accessing Powerpoint slides, and *information handling,* such as locating information resources and reviewing these within a shared virtual space (Littlejohn & Peglar, 2007:94)

The experiential learning that we are developing goes well beyond these norms and enables students to physically experience things such as visual effects, distortions, emphasis and visual direction caused by the brain processing visual inputs in particular ways. The intention is for a student to be able to interactively control the variables which make a visual effect occur. The multimedia is intended to conclusively demonstrate for them, that knowledge of how the visual system works can be used by designers to affect or even manipulate how a viewer takes in an image. It is important to reiterate that it is not on the basis of their passive viewing, but rather interacting with and adjusting the variables such as luminance levels, thresholds, rotations and so on, so that they can experience for themselves, the nature of the process and what triggers different effects. It is very much a participation model in which we are facilitators, rather than an acquisition model in which learning is knowledge that needs to be acquired. (Collis & Moonen. 2001:22). Some practical examples from the studies undertaken so far are shown below

Examples of experiential multimedia developed through this research

In Figure 1, the student is asked to drag the black square to the left or right until they feel that the whole composition of four squares is balanced. Research confirms that more time is spent looking at objects which are in the so-called 'centre of gravity' of a visual scene. This implies elements have a perceptual weight, and the student is basically judging for themselves where they experience the balance taking place.

There is no right or wrong in this exercise but it is interesting that of the hundreds of samples taken, most design students choose one of two positions marked by the red crosses in the third part of Figure 1. These positions indicate whether students were viewing the four squares in isolation or were seeing them as part of the whole space. Immediate online feedback discusses the implications of this for the student to reflect on.

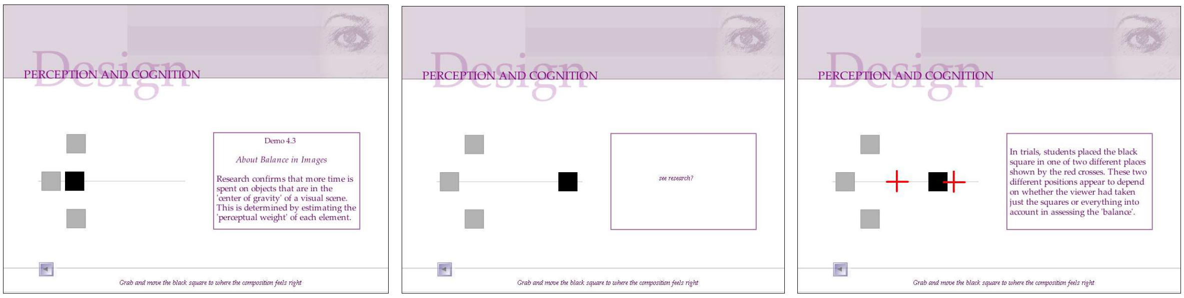

Figure 1. Experiencing balance or perceptual weight in a layout. End user drags the black square to where they think the layout is balanced and then receive feedback on trends with reasons

The authors have developed a series of demonstrations to show how various factors and precepts such as shading, occlusion, perspective, and haze contribute to the perception of three dimensional space. Figure 2 shows one small section from the series in which the student is asked to drag the slider to adjust the luminance (brightness) levels of the background. In doing this, the student can experience for themselves at what luminance level the scene feels most three dimensional. Immediate online feedback discusses results from a larger sample and reasons why this should be so as well as implications for design.

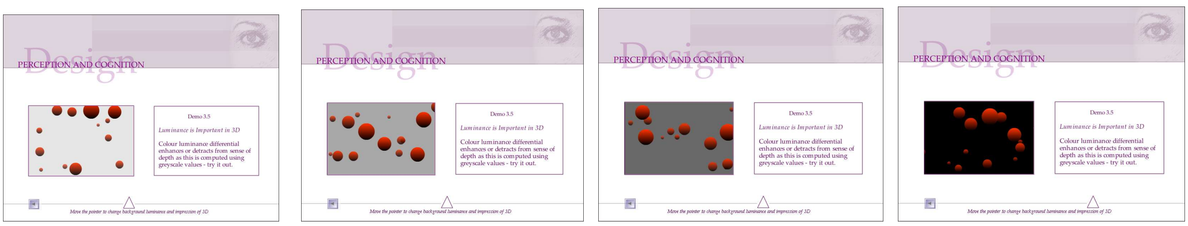

Figure 2. Slider control for end user to adjust background luminance until they 'experience' the point at which the spheres look three dimensional

In Figure 3, a photograph is seen normally. By pressing the button it is transformed into a line drawing and the student can experience different feelings from it. Lines, contours and edges are easier for the brain to detect than fills, and are part of the early image processing that happens in the brain. The physical experience from line drawings is actually different from seeing a photograph.

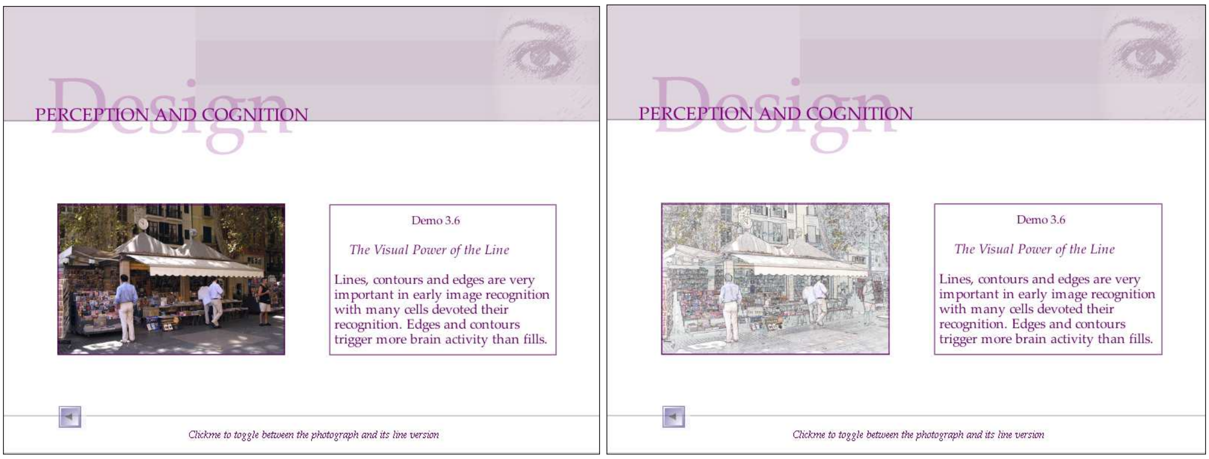

Figure 3. Toggle controls to convert photograph into line drawing and 'experience' the fact that lines, contours and edges which are so important in early image processing trigger a different kind of feeling in the brain

In Figure 4, two squares are clearly visible both containing a left-right gradient fill. The squares can be rotated by the student so that they can experience for themselves how much more difficult it is to distinguish the individual squares when there are no obvious lines or contours to detect. This is because individual brain cells have been shown to respond to specific orientations of lines. In fact, a whole system is in place inside our brains to detect lines, contours and edges - far more so than fills (Zeki,1999:113). One could speculate why this is so, but it would be reasonable to suggest that its purpose might be for fast recognition of objects and reduction in mental processing effort.

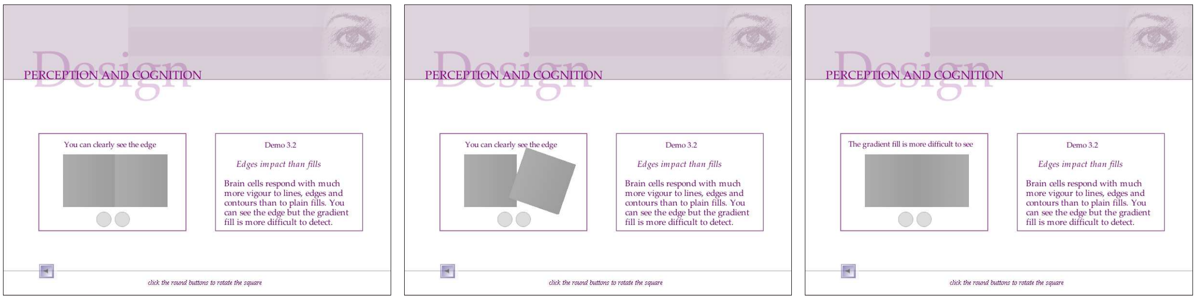

Figure 4. Rotating areas of gradient colour to 'experience' how much easier the brain perceives edges than shade or fills

The examples given are a small selection of the demonstrations we have developed which allow students to experience for themselves the effects that can be controlled in human vision by adjusting specific variables. Their ability to adjust those variables at a fine level of control means the Kolb cycle of experience-reflect-conceptualise-experiment can potentially happen very quickly with iteration following each fine adjustment. The fact that we are trying to engage the end-user's senses more so than with normal multimedia is a significant point. This illustrates the fact that 'people find it easier to remember things when associated with sensory recall' (Beard & Wilson. 2006:157)

The ultimate aim of this approach is to embed into the minds of design students a mental model of what is happening in the brain when they design something for viewing by an audience. This should empower them at some point in the future, perhaps when they have had enough opportunity to experiment with, and reflect on that knowledge, to become more effective designers, with a better level of control over visual language than has been possible before.

In terms of the chronology of experiential learning, we can learn from an event at the time it occurs (concurrent learning), and from past events by reflecting on them later (retrospective learning). However, prospective learning, 'the process of investigating possible futures involves a similar process to that of learning from the past and present experience.' (Beard & Wilson. 2006:38). It is what we would call imagining or visualising and is an essential component of our approach. Learning about vision science in itself is not enough. The whole point is to start imagining how it could be applied in creative work.

Some of the principles that we have covered are already known about in the arts and design world, (although perhaps not as easily demonstrable as we have tried to make them). However others are very much reliant on new knowledge gleaned from vision science such as the notion of equal brightness or equiluminance and how that can be used in design.

Analysis and design tools

In addition to the interactive learning materials described above, our research has also developed tools that can interactively analyse existing images. For example, one tool allows us to analyse any luminance levels we choose to set within an image, either for a set luminance level or within a specified range of luminance levels. This has revealed some very interesting findings. Another tool we developed allows us to investigate an image for evidence that proportions have been designed to reflect the golden section.

Much work has been carried out with eye-tracking technology and in colour testing laboratories to establish what factors guide the eye around an image. This has been an iterative process starting with theory and hypothesis, testing its accuracy, modifying an image and testing to see if the eye is guided any differently.

In addition to analysis tools, we knew from the outset that understanding vision science would be of little use unless we could apply that knowledge creatively within the field of design. Therefore, we had to develop tools which allowed us to apply the knowledge. For example, an understanding of vision at equiluminance has already been shown to have use in design. While colours are processed in one pathway of the brain and are part of the process of object recognition (ie. *what* is the object?), luminance (or brightness) of those colours is actually processed in a different part of the brain where it is used for spatial information (ie. *where* is the object located?). It is the interaction between these two parts of the brain which holds potential for creative use within design. Luminance levels however, are notoriously difficult to judge with the human eye (Livingstone, 2002: 66). In order to be able to use these colours in artwork we have therefore developed a tool which allows us to choose colours and then use the software to equalise the brightness levels to a set level. The equiluminant colour palette thus created can then be exported to industry standard software that designers commonly use. One of the authors has used this particular tool in creative design work which has won international acclaim.

Other vision science research

A small but growing community of researchers is now investigating how vision science can impact on design. For example, using knowledge of how the brain responds to lines and contours, DeCarlo and Santella worked on the basis that 'good information design depends on clarifying the meaningful structure in an image' (Santella and DeCarlo 2002:1). They took a computational approach that 'transforms images into a line-drawing style with bold edges and large regions of constant colour'. This was designed to reduce the perceptual effort required to take in the information from that image, making it more effective in communicating its content. They did not however, do this for the image as a whole. Instead, to make the abstraction meaningful, they used eye-tracking technology to identify which areas of an image were the most important, and then programmed algorithms to reduce details based on those levels of interest. In other words, the most important areas contain the most detail, while areas of least interest are reduced to 'suggestive contours' that provide visual cues for the brain to extrapolate image details, based on merely suggesting them. This approach seen in Figure 5, uses technology based on a model of perception to enable the transformation of a photograph into a painterly representation of it, using scientific understanding of how to communicate the most important elements.

Figure 5: (a) source image; b) fixation points gathered by eye-tracker; (c) the resulting line drawing

Images to match visual acuity

Our own research has looked at a number of areas of vision science, including design based on visual acuity, and builds on work by the visual psychologist Prof Stuart Anstis.

The resolution of the retina changes very quickly from high resolution at the fovea through to very low resolution at the periphery. Vision science findings from Anstis's work have provided data that allows us to calculate how big an object should be in peripheral vision, in order to be the same resolution as objects at the centre of gaze. It therefore becomes possible to work out object size dynamically in such a way that wherever you position objects, they should effectively appear to be the same resolution, or equally legible if the gaze is fixed at a specific location in relation to them. This is called metameric design, and can be useful in design situations where it is known that the target audience will only get one chance to glance at the design. 'Since the design of the display is optimally matched to the resolution of the eye, it might have applications in conditions requiring maximum transfer of information during a single fixation' (Anstis 1974: 590).

We have taken retinal resolution data provided by Anstis and others, and used it to develop software that allows us to drag letters and shapes and have them dynamically change size to match the resolution of the eye. As long as the gaze is fixed on the central point, all the letters or shapes should appear equally legible, because they are of equal resolution.

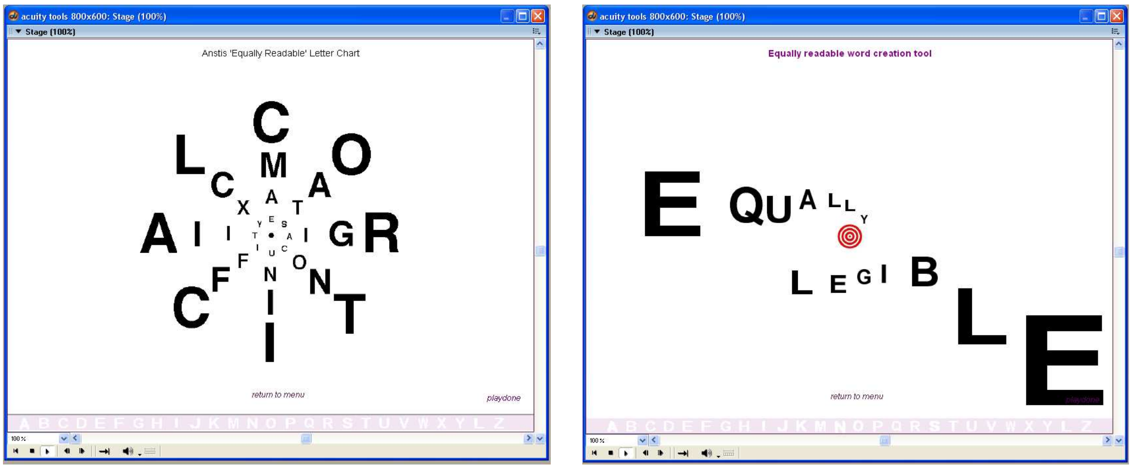

Figure 6:
(a) Anstis chart showing equally readable letter sizes when gaze is fixed at centre
(b) Authors' interactive design tool allowing dynamic resizing to match retinal resolution

Table 1 Areas of vision science relevant to design education

	Stages of perception	Aspects of perception and cognition relevant to design	Areas of visual science research relevant to design *	
1	Input to the eye:	**Improving first impressions:** 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	**Highlighting the essential**: 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	**Making use of visual hierarchy:** 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	**Enhancing recognition**: 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	**Steering the eye:** 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	**Controlling meaning**: 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	**Controlling interest:** Using form and composition in design to influence aesthetic appreciation.	• Rule of thirds • Use of ratios • Fibonacci series • Symmetry, • Alignment, • Aesthetic illusion	• Colour • Signal to noise ratios • Top down lighting bias • Visual problem solving • Golden ratio toolset • Colour balance

Note that the areas of vision science understanding listed in column 3 are all linked to multimedia examples, demos or tools

Establishing a framework to identify areas of relevance to design education

In developing this research since 2003, a very large range of vision science factors were noted as well as a large range of arts and design rules and principles. In trying to organise all of these possible lines of investigation, it was clear that we needed a framework which would allow us to map the subject matter from vision science onto the subject matter for arts and design. This would then allow us to identify areas where the two fields overlap and where new knowledge had not yet filtered through from one area to the other.

Our response was to develop the framework shown in Table 1, which is still very much a work in progress. It is a starting point for enabling discussion and allowing us to see at a glance just how vast this field of knowledge is.

To make it most useful for our research, we needed to organise the information in terms of the stages that human beings perceive images. Our work is less concerned with cultural interpretations that people might apply *after* they see an image, and more with *how* they actually see it in the first place, so stages of perception made most sense for us.

We also developed interactive multimedia materials linked to most of the subject areas listed in the right hand column, so this table became an interactive learning resource allowing us to see interactively the theory, issues and demonstrations relating to any of those subjects. 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 this works in practice. If you are reading an electronic version of this text with access to the web, then CTRL/click on 'Depth cues' or 'Orientation sensitivity' - to see some example movies

This chart although simple in concept holds the key (via the links to interactive multimedia) to making working connections between vision science understanding and its application in art and design practice.

Conclusions

Past DEFSA papers have talked about Outcomes Based Education (OBE) with its roots in constructivist theory as being the system prescribed for design education in South Africa (Costandius 2006:1). This paper has examined practical examples of an approach to multimedia experiential learning that fits well with the OBE approach.

Designer educators and forums like DEFSA need to begin a programme of

1. proactively identifying aspects of science that are relevant to design education and maintaining currency as that knowledge develops
2. distilling any scientific language or 'technobabble' into the key points that a practicing designer would need to know and
3. producing tools that allow such knowledge to be analysed and more importantly applied in the field of design

Many papers and researchers are 'talking' about the importance of making links between science and the arts. Indeed many research grants are available for this purpose. Our research has gone much further than discussion, and actually programmed the algorithms which make this possible in a very practical way.

This area of knowledge cannot occupy more than a fraction of the design curriculum, and at this point we are not suggesting that it should. We believe, however, these are the first tentative steps in a process that the whole design community should be developing more proactively, so that this relatively new knowledge can genuinely feed into and support the design practices that we are so passionate about.

Intuitive work and visual awareness will always be important in the field of design practice and education. That is not likely to change any time soon. However, vision-directed design gives us the opportunity to go beyond the intuitive, and explore a more objective way of designing based on a better understanding of how a human being will respond to specific types of visual layout and content. From our study and work so far of making vision science knowledge more accessible to design education, we plan to build on the framework and the related suite of multimedia connecting visual science understanding to design practice. We strongly believe that design schools need to begin introducing formal tuition about where vision science and design overlap. Vision science should not be seen as something separate from creative endeavour, but something that can potentially enhance it.

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Curriculum Vitae

Gurpreet Singh: MSc. DMS. Cert.Ed(HE). BA(Hons). MEADiM, Chartered MCIPD

Gurpreet Singh is a Principal Lecturer and Acting Head of the Dept of Design at University of Sunderland, UK. He started his career in architectural design from which he developed into computer graphics, and later into human-computer interface design and multimedia programming. These now play key roles in his research.

He leads the only course in the UK to be chosen for the prestigious Computer Arts Graduate showcase for ten years in a row. His multimedia students have won accolades across the world including winner of the biggest multimedia competition in Europe - the Europrix.

Working with his colleague Mike Pickard, he has published a number of international papers about the relationship between design and vision science. He also designs creative installations for art galleries and exhibitions on the theme of spirituality and multimedia, and is an invited member of the European Academy of Digital Media.

Michael Pickard: BSc. BA(Hons). MA(Disttn)

Michael Pickard studied engineering at London University and Business Studies at the Geneva Business School in the course of a lifetime career in industry. This included working in a variety of managerial roles starting out as a design engineer and ultimately working as an overseas business director for an international company with world wide interests. He has worked in a diverse range of countries as far afield as Russia, the Indian subcontinent and the United States but has always maintained an enduring interest in art and design.

More recently, he returned to the academic life, in order to take a BA and MA in design, multimedia and graphics and is now a Research Fellow at Sunderland University where he lectures and conducts research in design related topics. The current research being undertaken is part of a larger project at the University concerned with making better connections between the visual sciences and art and design practice. The overall objective of this is to find ways of bridging the gap between the visual sciences and the visual arts so as to provide the basis for an educational approach to equip students with new knowledge about vision that can be useful in their creative work. He is a committed countryman with many interests now living on the North Yorkshire Moors and London.