Go to contents 07

# CADD Curriculum

## *The Issue of Visual Acuity*

*PROCTOR, George*
*Department of Architecture, California State Polytechnic University Pomona*
*http://www.csupomona.edu/~arc/* *grproctor@csupomona.edu*

*Design educators attempt to train the eyes and minds of students to see and comprehend the world around them with the intention of preparing those students to become good designers, critical thinkers and ultimately responsible architects. Over the last eight years we have been developing the digital media curriculum of our architecture program with these fundamental values. We have built digital media use and instruction on the foundation of our program which has historically been based in physical model making. Digital modeling has gradually replaced the capacity of physical models as an analytical and thinking tool, and as a communication and presentation device. The first year of our program provides a foundation and introduction to 2d and 3d design and composition, the second year explores larger buildings and history, the third year explores building systems and structure through design studies of public buildings, fourth year explores urbanism, theory and technology through topic studios and, during the fifth year students complete a capstone project. Digital media and CADD have and are being synchronized with the existing NAAB accredited regimen while also allowing for alternative career options for students. Given our location in the Los Angeles region, many students with a strong background in digital media have gone on to jobs in video game design and the movie industry.*

*Clearly there is much a student of architecture must learn to attain a level of professional competency. A capacity to think visually is one of those skills and is arguably a skill that distinguishes members of the visual arts (including Architecture) from other disciplines. From a web search of information posted by the American Academy of Opthamology, Visual Acuity is defined as an ability to discriminate fine details when looking at something and is often measured with the Snellen Eye Chart (the 20/20 eye test). In the context of this paper visual acuity refers to a subject's capacity to discriminate useful abstractions in a visual field for the purposes of Visual Thinking- problem solving through seeing (Arnheim, 1969, Laseau 1980, Hoffman 1998). The growing use of digital media and the expanding ability to assemble design ideas and images through point-and-click methods makes the cultivation and development of visual skills all the more important to today's crop of young architects. The advent of digital media also brings into question the traditional, static 2d methods used to build visual skills in a design education instead of promoting active 3d methods for teaching, learning and developing visual skills. Interactive digital movies provide an excellent platform for promoting visual acuity, and correlating the innate mechanisms of visual perception with the abstractions and notational systems used in professional discourse. In the context of this paper, pedagogy for building visual acuity is being considered with regard to perception of the real world, for example the visual survey of an environment, a site or a street scene and how that visual survey works in conjunction with practice.*

***Keywords:*** *Curriculum, seeing, abstracting, notation*

Go to contents 07

## Background

The introduction of visual skill building in the early years of an architectural design program is typically combined with an introduction to graphical notation systems for representing visual ideas. The ideas and notational systems students are introduced to do not necessarily represent what is naturally perceived but reflect emphases of the discipline. While many students given an explanation do recognize principles described in the notational systems used in architecture, generally it is a language unfamiliar or new to a majority of entry level students. Students in short order are asked to think, create, and represent in notational systems peculiar to architecture with the same level of fluency a language major is asked to compose written works in their native tongue. (The English major, for example, most likely has 16+ years of experience speaking English). Architecture students, uncertain of the semantic and syntactic functions of the discipline's graphic notation system struggle to translate data freely from perception to notation and back to work in the perceptual world. (This presupposes that the discipline of Architecture has a universally defined and accepted notational system for recording perception).

Betty Edwards suggests in her book, Drawing on the Right Side of the Brain (1979), methods for developing the capacity to abstract from what is perceived. Paul Laseau's book, Graphic Thinking for Architects and Designers (1980) outlines generally accepted material an architect should learn to perceive, a graphic notation system for representing what is seen and operations that can be applied to notational elements. Other authors also describe similar material (e.g.- Ching, 1979; Porter & Goodman,1985).

Much of what can be found in these texts on traditional architectural drawing may also be described as a system of diagramming. Diagrams are used to explain how something works or to clarify the relationship between the parts of a whole (AHD, 2000). Peter Eisenman discusses diagrams functioning as both "...an explanatory or analytical device and as a generative device. While it (the diagram) explains relationships in an architectural object, it is not isomorphic with it." (Eisenman, 1999). In this statement, Eisenman points out the diagram's limitations. Abstractions effective in visual thinking must maintain relevant features of their referents- they should be isomorphic (Arnheim, 1969). So if students are being asked to learn how to look, while being taught a notational system with questionable isomorphic correlation to what they should be looking at, confusion or a lack of clarity might be expected in their visual thinking. The quest for a tool(s) for actively teaching and learning visual thinking skills may well have emerged with expanding use of digital media. Digital media and the Internet have arguably made visual skills much more important in the last dozen years. Digital media tools have the capacity for (re)training the eyes of young architects to see patterns and abstractions relevant to visual thinking in architecture, while taking into account how humans naturally perceive.

## Visual Perception

Perception often involves multiple senses however in the context of this paper it refers to the process or act of becoming aware or observing, through sight (AHD, 2000). "Seeing comes before words. The child looks and recognizes before it can speak." (Berger, 1972)

Visual perception as noted by Berger and others, precedes a capacity for internal abstract thinking. Arnheim goes further to suggest that the eye is selective, and abstracts and simplifies before sending information to the brain (Arnheim, 1969 p.20). This simplification of data is necessary to avoid a flood of information to the brain and helps to establish concepts with which to think. (Arnheim, 1969, p.26). Understanding these innate functions of the eye and mind is a precursor to formulating how the eyes and visual skills of an architecture student may be trained.

The retina, an array of receptors at the back of the eye is sensitive to light. Visual processing begins with these pointwise measurements of light intensity

Go to contents 07

(Mahoney, 1987). Meaningful physical entities in an image array may have widely varying spatial extent, may appear in a variety of shapes and configurations and their meaning may depend upon the task at hand. Moreover, these entities are not explicitly described in the image array. Vision chunks an image array searching for regularities (simplifications/ abstractions), properties and relations. (Mahoney, 1987 p.12). Vision is selective and scanning, searching for change. The survival instinct has evolved the eyes to be sensitive to changes in a visual field that may reveal both threat and opportunity. (Arnheim, 1969) Repeated or constant stimulus has a tendency to be ignored and/or simplified. (Norman, 1988, p.54-80) For example most people see and recall the sky as just blue rather than as a gradient with all the variations of color and texture due to clouds and/or atmospheric density. Additionally, ocular fixation, fixing the retina on the object of attention, concentrates the narrow range of sharpest vision on a subject, placing the subject and the field-of-view around it into an "inner world". New subject matter entering this field-of-view comes from an "outer world" and is accommodated and absorbed into the "inner world" with a realignment of the retina. As well, the eye selectively discerns depth and in the process eliminates or adds to the field-of-view. Realignment of the retina and/or the expansion and contraction of the field-of-view (change in depth) is activated somewhere between conscious effort and automatic response.

The perception of shapes is the precursor to concepts and indicates a grasp of structures in the visual field. Shapes are often accompanied by visual noise that may modify the shape with limited affect on visual comprehension. Complex shapes are seen as combinations of simpler forms. Vision often completes incomplete objects in a field of view. (Color is recognized in a manner similar to shape, as simplified color (red, yellow, blue) with more complex colors being combinations of elementary color.) Objects are separated from their context in order to understand relation and structure- how they are either a part of the context or their context affects them and, to understand how the object changes or is modified as it moves from one situation to another. "In spite of retinal variation, the mind's image of an object is constant, at least approximately so: the object has and maintains its own- size, shape, brightness, and color." (Arnheim 1969, p.38) "Evidence is inconclusive as to whether shapes are instantly recognized or require repeated exposure. Evidence also indicates graspability of shape and color varies between culture and by training." (Arnheim, 1969 p.31) Publications of the AI Lab at MIT suggest that meaningful scene entities, their relevant properties, and relations cannot be detected at once requiring resources for visual processes to be goal driven and spatially focused (Mahoney, 1987 p.13).

In his book, Visual Intelligence, Donald Hoffman defines several axioms and 35 rules for how the eyes and mind operate to extract and decipher visual data. The rules are relied upon to enable the mind to quickly resolve the contents of a visual field working so quickly that the constructions made from these rules at times mask a reality visible only with conscious effort. Sight is not the only sense that operates in this manner as Hoffman illustrates through case studies in his book. (Hoffman, 1998) Hoffman is acknowledging the assumptions internal and sub-conscious cognitive mechanisms rely upon for visual perception, and by inference the criticism of empirical evidence acquired by sight. However, he is pointing out that we construct our perception of the world similarly with the other senses. Hoffman states several axioms before outlining his visual rules:

*"The fundamental problem with vision: the image at the eye has countless possible interpretations." (Hoffman, 1998, p.13)*

*"The fundamental problem of seeing depth: the image at the eye has two dimensions; therefore it has countless interpretations in three dimensions." (Hoffman, 1998, p. 23)*

*"The fundamental role of visual rules: you construct visual worlds from ambiguous images in conformance to visual rules." (Hoffman, 1998, p. 24)*

So to provide effective visual training for young architects we should: 1.) Acknowledge the internal cognitive mechanisms used to construct visual perception, 2.) Use the rules of visual intelligence to identify and organize visual data used to train the eyes of future designers of human environments 3.) Identify the conditions under which visual rules may provide false perception and, 4.) Use notational systems that correlate with rules of visual intelligence.

## Abstraction

Abstraction is a bridge between perception and thinking. One perceives in particulars and thinks in generalities. Abstractions from the visual field are used for conscious and unconscious analysis. Arnheim states the eye is selective, and abstracts and simplifies before sending information to the brain (Arnheim, 1969 p.20). For example your vision discerns the words on this page while your mind is focused on their meaning. The information abstracted from perception is stored in short-term memory and is limited to approximately seven items. This information can be stored in the brain as arbitrary collections (such as memorizing the alphabet), relationships to things already known (relating to things previously acquired gives structure and organization) and as an explanatory mechanism (Norman, 1988, p.67). Explanatory mechanisms (mental models, symbols) are one of the most powerful forms of remembering because much of the information does not have to be stored in memory. Symbols/mental models help us assemble masses of information (even though we seem to be able to keep about seven things in our minds at once), they are like Trojan Horses of the mind(Norman, 1988, p.70).

Work from the AI Lab at MIT states a subject viewing a three-dimensional object appears to rely upon internal canonical views to recognize the object. This seems to be the case even if other views of the object are seen equally often. (Edelman, 1991) If an object is not aligned with the internal canonical view, the subject relies upon mental rotation to match an internal representation. (Edelman, 1991) Taking this further, we can say the internal canonical views most effective are abstractions maintaining relevant features of their referents. They are visually isomorphic. Abstractions are not transferable between different perceptual situations (Arnheim, 1969; Norman, 1988). Abstracted percepts become thoughts to be manipulated and processed. These thoughts, conceptual models, need not be very complex, just adequate and correct. (Norman, 1988)

In considering the use of abstraction for the visual training of architects, it seems appropriate to adopt notation that builds upon the function of abstraction as an internal or computational process. Further review of material from the AI Lab at MIT describes general requirements of visual spatial analysis that may provide some assistance. 1.) require information from a visual field to be abstracted (identified computationally); 2.) the abstraction must be open ended, meaning not all possible variations can be pre-determined so the abstraction can accommodate future possibilities; 3.) the abstraction must remain intact when complicated by location, spatial extent, variety in size and shape, and quantity (Ullmann, 84).

## What should young architects be seeing when looking at a visual field or image

With both the eye and the mind participating in the process of looking and abstracting, a case can be made for investing time to carefully re-train both the eyes and minds of young architects. In teaching, I often physically point out what to look at, describe what to look at and, graphically abstract for students what to perceive in a variety of media. Even approaching the subject of visual acuity from many fronts does not seem to produce immediate satisfactory results in a majority of young students. While some students, particularly the bright and sensitive students seem to quickly assimilate principles though static 2d methods, many do not, pointing to some underlying obstacle. Some of this may be attributable to individual psychophysical conditions, cultural barriers, the pressures of student

Go to contents 07

life and even teaching methods. My argument suggests that this has much to do with the traditional system of visual training with 2d methods, including how to look and the language of notation, is not synchronized with innate functions of sight and visual perception.

Recall that constant stimulus has a tendency to be ignored by the eye and mind and overly simplified. What needs to be seen for architectural purposes may be included in information that naturally becomes overly simplified, discounted, or may not be naturally or commonly perceived. The eyes have evolved to be selective, scanning, depth adjusting, and searching for threat and opportunity. The eyes are alert to motion and change. Architecture and the principle visual issues of a site are somewhat fixed or of a very long duration. The eyes look for shape, structure and color, all items an architect should be aware of, however, the way in which these items are naturally perceived and internally referenced is most likely different than how the culture of architecture will expect them to be perceived and stored by young architects.

Ultimately what is perceived and abstracted will be used in visual analysis, used as a design tool and, used to frame arguments. For perception and abstraction to be useful, it needs to be socially cogent. The elements of visual thinking vary somewhat between the references considered for this paper. However, it appears that there is some general consensus within the discipline of architecture. In reviewing a number of texts on visual thinking and awareness making reference to architectural training, I found the primary list of visual elements and ideas of each author provides a somewhat varied foundation for visual thinking. The correlation to innate rules of visual perception is not clear. Part of the problem is that many of the visual elements noted in these texts do not operate at a fundamental level, but are instead complex and higher level visual ideas (see the lists outlined below). From the material investigated for this paper, Hoffman's 35 rules (not all listed below) are intended to provide a collection of principles for emulating human visual thinking as artificial intelligence (Hoffman1998). These 35 rules may provide the most transparent connection between fundamental elements and mechanisms of visual perception and, complex higher level visual abstraction and thinking used in architectural discourse.

*Author* Visual Elements/Ideas

*Taylor (1981, p.91)*

Shape, Proportion, Texture, Color, Relationship of Parts, Context

*Laseau (1980).*

Line/Structure, Tones, Texture/Color, Detail, Drawing Types

*Edwards (1979)*

Edge, Contour, Shape in Positive and Negative Space, Perspective, Proportion, Light and Shadow

*Arnheim (1969 p.13)*

Active Exploration, Selection, Grasping of Essentials, Simplification, Abstraction, Analysis and Synthesis, Completion, Correction, Comparison, Problem Solving, Combining, Separating, putting in context.

*Ching (1979)*

Primary Topological Elements (point, line, plane, volume), Form, Space, Organization, Circulation, Proportion and Scale, Principles, Rules of perspective -

*Woolsey (1997)*

Shape, Pattern, Relationships

*Hoffman (1998) e.g.*

Rule 12: If two visual structures have a non-accidental relation, group them and assign them to a common origin.

Rule 13: if three or more curves intersect at a common point in an image (meaning-on the retina), interpret them as intersecting at a common point in space.

Rule 22: Interpret abrupt changes of hue saturation and brightness in an image (meaning-on the retina), as changes in surfaces.

Go to contents 07

(Excerpted from this list for the purposes of the QTVR tool described at the end of this paper: shapes and outlines, contiguous fields, lines of perspective, color, patterns, relationships, shade and shadow.)

## Methods for learning what to see

A number of tools for building visual acuity are available to the young architect. Informed looking, drawing and sketching, photography, digital photography and video all can and have been used to train the eye to see and generate useful abstractions for visual thinking. Building visual acuity is an iterative and procedural activity developed through practice and repetition. The ultimate purpose of visual acuity is clarification of what is perceived (Arnheim, 1969; Laseau, 1980).

One method of learning how to look is the traditional expository lecture accompanied with images. Simply being informed about what and where to look is a beginning for training the eyes how to look, however, declarative knowledge does not translate to procedural knowledge (Norman, 1988). And as it has been shown that words act as pointers to referents, a description of what to look at presupposes some internal visual reference (Arnheim, 1969). (Animals display evidence of thinking without benefit of language (Arnheim, 1969). Verifying that what needs to be seen, is seen, will need to be corroborated as an act or a process in the perceptual world. In terms of architectural pedagogy, this is best accommodated with graphic notation, assuming a socially accepted notational system exits and that it has been learned. By inference, it seems that the lecture with images is not a complete method for conveying and testing visual acuity.

Many of the methods used in visual skill building are followed as an iterative process, for example, one may sketch to see an abstraction, the drawing becomes part of the perceptual realm which in turn informs a new iteration of the abstraction leading to greater clarification.  Betty Edwards outlines a series of drawing exercises as methods for realigning how to look, bypassing existing symbol systems with the byproduct being improved drawing skills. The collection of exercises outlined in her book, Vases/ Faces, upside-down drawing, blind contour drawing, negative space drawing, using a view finder, use of paper edges for sighting, all take into account how the eye perceives and abstracts. The intention of the exercises are a (re) training of the eyes to see specific patterns and abstraction useful for visual acuity through exercises that make conscious the patterns seen. While the Edwards exercises have shown positive results, the exercises alone do not produce a complete pedagogy for building visual acuity, abstraction and notational conventions.

In his texts, Paul Laseau makes a case for sketching and drawing as a principle means for looking. Drawing is the act of abstracting from perception but its effectiveness is a function of skill. And if the skill of its user is undeveloped, the drawing created presents an abstraction that is inherently, isomorphically compromised. Arnheim describes drawing as a tool for personal clarification. His examples of children searching for relevant structural features of a subject, finding adequate shapes for those subjects with lines on paper, discuss the early development of visual thinking and do not necessarily provide a model for advanced visual thinking as needed in a professional discipline (Arnheim, 1969 p.255). Drawing is used within the discipline of architecture to capture perceptions, to explore ideas and, to represent ideas for use in practice. (I believe we can add to this discussion that drawing also works to clarify what is seen by the mind's eye.) Architectural drawing, albeit done by individuals, ultimately is a social act and has a social purpose and therefore must follow a set of conventions. Drawing conventions have been established more completely for practice. However, drawing as a tool for capturing and abstracting perception is left as the same act of personalized clarification Arnheim describes in children. This may be appropriate if one considers the entire process of architectural drawing from the early, personalized abstract drawings of an individual through the socially accepted conventions of team

Go to contents 07

produced drawings used to make buildings (working drawings). However, with the advent of digital media drawing technology, the process of drawing is being modified. Iteration in drawing still clarifies however, this clarification comes much earlier in the process. While these drawings probably remain obtuse to the layperson, they are more specific and less abstract to the architect, putting greater emphasis and importance on initial visual perception and thinking.

Another means to visual training, Photography, captures images that can be reviewed indefinitely and apart from a context. However, a photograph is a captured moment and comes with a fixed ocular position (the author's perception), eliminating the capacity for scanning and checking for difference- one of the natural functions of visual perception. Digital Photography is similar, however the file created for a digital image has tremendous utility for verification of color, form and pattern through image processing- it may be sampled directly from a captured image. (Of course an analog image can also be digitized for the same process.) Processed images can be mined to reveal distinct abstractions, lines, shapes, and underlying pattern. Video also comes with a fixed ocular position however, as a series of images captured over time, some amount of scanning and checking for difference is possible. Video can also be processed with software in the same manner images can be processed for abstraction.

So we can tell someone what to look at and by so doing cause awareness. But visual acuity must validated with an act. For this we have long used drawing. The act must be transparent and usable by others- it must follow a set of socially derived conventions. In architectural culture, drawing has provided the process through which visual awareness is developed, validated, and shared with others. As a person who uses both digital media and drawing as a tool for capturing visual data, I do not see drawing going away. Instead I see freehand sketching growing in significance as an interactive process of seeing. Drawing causes the actor to take the time to look. Time spent looking may be the real ingredient for building visual acuity over any specific method of visual skill building. However, conversely, I have found personally and from my colleagues, that constant use of digital modeling tools and viewing in both wire frame and rendered modes has a propensity for improving freehand drawing skills. The time spent seeing the rules of perspective displayed on a 2d screen (wire frame mode) in combination with the perceived depth of field and 3d experience of the rendered views allow functions of natural perception to be corroborated with architectural drawing. This brings me back to the issue of teaching visual awareness to young architecture students, now most of whom have grown up with a mouse in their hands playing interactive video games. They are showing incredible dexterity with the digital tools I teach but they often struggle (in comparison with similar students of 5-8 years ago) to see when provided with only a verbal explanation. They may claim to understand conceptually but do not show evidence of seeing. However, when they do show evidence of seeing, it comes through process than from having been told- which may have much to do with the procedural nature of software use. I see the real causal factor as taking the time to focus and make what is seen conscious.

## QTVR as a Tool for Teaching Visual Acuity

I have undertaken a project to combine the issues of visual skill building with software use. This has been attempted before in the CD-ROM, VisAbility. This interactive training tool provides a series of ideas regarding what to see, along with interactive tools teaching how to draw and diagram. This instructional media may be one the first proactive examples making the connection between visual training and digital technology. In VisAbility, the principle exercises are 2d and not spatially oriented, and therefore probably not sufficient for architecture students.

When this project began, the use of the interactive movie using Apple's QuickTime VR (QTVR) was still somewhat novel. The QTVR or interactive movies generated with similar technology can now be found

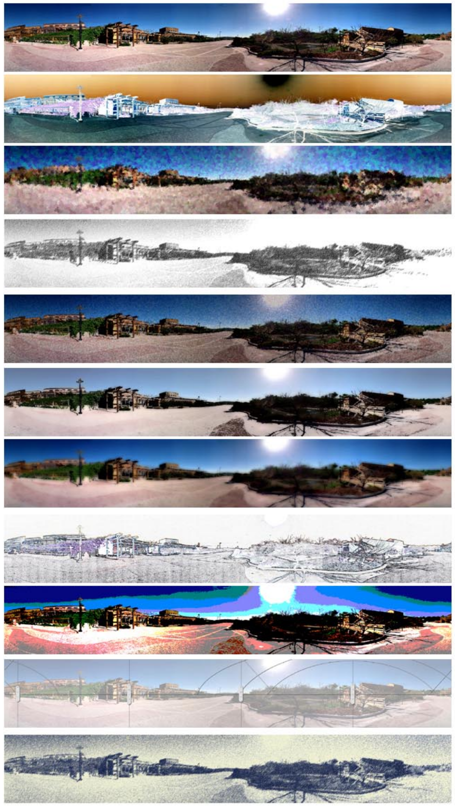
Go to contents 07

*Figure 1. Example Processed File*

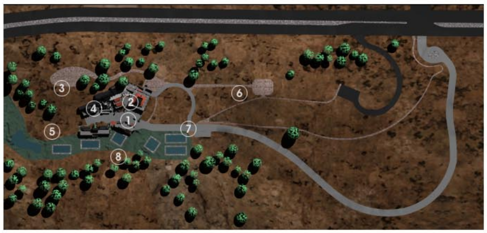
on real estate, product and auction web sites. It is an inexpensive interface providing the user with the sense of looking where they want at their own discretion. QTVR movies are used to view objects rotating about a fixed point or, may be panoramic, viewing a space from a fixed point. Viewing the movies of this study, is like wearing special goggles with a series of user controlled filters built into the lenses; lenses allowing an instant capacity to see the essence of what is being viewed as lines, or color, or shapes, or pattern and so forth. Possibly similar to the glasses described by William Gibson in his book Virtual Light (Gibson, 1991) (in Virtual Light, as the user realigns their retina, annotations on the lenses change to correspond with the new subject).

QTVR movies are actually captured digital images, viewed with QuickTime (or similar software) to appear as seamless interactive object or panoramic movies. (Object movies appear to the user as an interactive rotation of a fixed subject. Panoramic movies appear to the user as an interactive 3600 pan from a fixed point.) As digital information, the images can be processed, with image processing software, such as Photoshop, to reveal the abstractions of perception, and to represent graphic notation useful in architectural discourse.

In the context of this project, the QTVR movies are meant to build visual acuity through the use of an interface organized to reinforce pedagogic issues of architectural education. For this study, a series of interactive panorama movies were captured and processed to reveal a series of distinct abstractions. These abstractions include both simplifications the eye makes in the process of deciphering a visual field and notation used by architects. The images in the movies have been processed to reveal shapes and outlines, contiguous fields, lines of perspective, color, patterns, shade and shadow, text and notation (see figure 1). For example, the movie can be viewed revealing only the patterns of shade and shadow or, viewed to exclusively indicate the shapes which make up a picture plane or, displayed with the paths and temporal locations of the sun as a grid painted across the sky, and so forth.



Sample Node One




**QTVR as a Tool for teaching Visual Acuity**
*George Proctor, Cal Poly Pomona*

Go to contents 07

The series of captured and pre-processed images (movies) representing the spectrum of possibilities from a specific 3600 pan, are displayed within an interface built in Macromedia Director. The interface allows the viewer to not only pan and zoom at will but also allows the user to switch between the pre-processed versions of the movie at will. Thus allowing the user to see a correlation between what is seen and various abstractions and forms of notation. QTVR movies can also be linked together allowing the user to shift their point of rotation and their perception of what is being viewed. A user may only shift their viewpoint if another node(s) have been captured and linked to the original movie.

Preliminary results from the tool's use show a capacity in students for improved visual acuity. The project is suggestive of further work. Software may be written to process (abstract) movies in real time (on-the-fly) as needed and, hardware (which may already be under development for military application), such as display goggles, may eventually make the process available as a real-time, real-world experience.

## Summary

The quest for a tool(s) for actively teaching and learning visual thinking skills may well have emerged with the expanding use of digital media. Digital media and the Internet have arguably made visual skills much more important in the last dozen years. Regardless of what methods are used, visual acuity is a fundamental design skill and needs to be developed. Digital media tools do illustrate a capacity for (re)training the eyes of young architects to see patterns and abstractions relevant to visual thinking in architecture, while taking into account how humans naturally perceive. But finally it may be the amount of time invested in building the skill, regardless of method, that provides the greatest benefit.

## References

Arnheim, Rudolf:1969, Visual Thinking, University of California Press, Berkeley.

Berger, John: 1972, Ways of Seeing, Penguin London.

Edlemen, S., H. Bultoff, E. Sklar: 1991, Task and Object Learning in Visual Recognition. AI Memo 1348, Massachusetts Institute of Technology, Artificial Intelligence Laboratory.

Edwards, Betty: 1979, Drawing on the Right Side of the Brain, J.P. Tarcher, Los Angeles.

Elkins, James: 2000, How to Use Your Eyes, Routledge, New York.

Gardner, Howard: 1982, Art, Mind, Brain. , Harper Collins, New York.

Hoffman, Donald: 1998, Visual Intelligence, Norton Publishing, New York.

Laseau, Paul: 1980, Graphic Thinking for Architects and Designers, VNR, New York.

Marill, Thomas: 1992, Why Do We See Three-Dimensional Objects? AI Memo 1366, Massachusetts Institute of Technology, Artificial Intelligence Laboratory.

Mahoney, James: 1987 , Image Chunking: Defining Spatial Building Blocks for Scene Analysis AI-TR 980, Massachusetts Institute of Technology, Artificial Intelligence Laboratory.

Norman, Donald:1988, Design of Everyday Things, Doubleday, New York.

Pickering, John, Martin Skinner (ed.): 1990, From Sentience to Symbols, University of Toronto Press, Toronto.

Taylor, Joshua: 1981, Learning to Look. Chicago: University of Chicago Press, 1981.

Woolsey, Chistina Hooper, Scott Kim, Gayle Curtis: 1987, VizAbility, PWS Publishing, San Francisco.