THREE DIMENSIONAL COMPUTER GRAPHICS ANIMATION: A TOOL
FOR SPATIAL SKILL INSTRUCTION

DISSERTATION

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CHAPTER 1

INTRODUCTION

Home Economics college students studying in the area of housing design and analysis find it necessary to make use of basic architectural drafting skills. These skills include producing and reading orthographic drawings of interior spaces.

In experiences of teaching beginning drafting skills to Home Economics students at The Ohio State University, vast differences in students' abilities to utilize spatial relations became apparent to this researcher. Inabilities to work with scale, correctly sketch the floor plan of an existing house, and project elevations of a floor plan, were some of the major problems.

Although various instructional materials, such as step by step drawing procedures and extensive drafting examples, helped inadequate students, it became clear that these techniques offered only a "Band-Aid" solution. The inability to draft house plans would seem to indicate a lack of higher order skills in spatial cognition.

An interest in three dimensional computer generated graphics animation led this researcher to question whether visual images created by a computer could be used to improve one's spatial cognition; and if so, which visual stimuli would be more effective than others.
Background

In this section, the following issues will be discussed briefly: a definition of spatial cognition, trainability and measurement of spatial abilities, the relationship between architectural drawing and spatial abilities, and computer generated visual techniques applicable to spatial instruction.

Spatial cognition has been defined by Hart and Moore (1973) as an internalized reflection and reconstruction of space in thought. This definition implies a distinction between what is initially seen (perception) and what is finally assimilated by the person (cognition).

Werner (1948) clarified the distinction between cognition and perception further. He defined perception as a form of cognition. As a person develops, perception becomes subordinate. Cognitive structures begin to dictate selected fields of attention. Thus, spatial perception would be immediate figurative knowing, whereas spatial cognition would be operative, based on a person's cognitive structures.

Is it possible to improve a person's spatial abilities? Research would seem to so indicate. Brinkman (1966) maintained that while some aspects of perceptual organization may be genetically influenced, other factors such as discrimination and judgment can be influenced by learning. He found that students who had participated in a three week programmed instruction course on spatial skills, performed significantly higher than the control group on a test of spatial relations. Others, (Evans, Marrero, and Butler, 1981; Evans and Pezdek, 1980; Gibson, 1953; Siegel and Schadler, 1977) have found
similar results. There is some indication that persons at the formal
operational level may benefit more from training than those at a
concrete level (Baltista, Talsm and Wheatley, 1973; Hill and Obenauf,
1979).

Measurement of spatial abilities has taken a variety of forms. To
identify developmental characteristics of spatial cognition, Piaget and
Inhelder (1967) used spatial tasks which required the use of models or
objects and a one-on-one interview technique.

Paper-and-pencil type tests can be used to determine spatial
abilities in either one of two areas, spatial visualization or spatial
orientation (McGee, 1979; Thurstone, 1950). Spatial visualization is
defined as "an ability to mentally, rotate, twist, or invert pictorially
presented visual stimuli" (McGee, 1979, p. 3); whereas spatial
orientation requires an understanding of the arrangement of elements
within a visual stimulus pattern, while utilizing the body orientation
of the observer (McGee, 1979).

Graphic representations can be produced by either freehand or
technical means. The relationship between freehand drawing ability and
spatial skills would seem to be unidirectional. While spatial skills
assist the artist or drafter, they do not automatically insure drawing
ability (Arnheim, 1974). Freehand drawing requires eye-hand
coordination and manual dexterity that not all persons with competent
spatial ability would possess. However, technical drawings are
accomplished with the aid of a straight edge and a measuring device,
eliminating the "drawing barrier" between a person's mental
representation and what is actually drawn.
The drawing/spatial relationship is further complicated for the architectural drafter. As described by Evans (1980), the drafter is an interactive part of the environment being drawn. The environment surrounds the observer and is viewed from multiple vantage points as it is explored. There is uncertainty as to whether theories in spatial cognition developed by cognitive psychologists apply to experiences in the environment. As was pointed out by Ittelson (1973), research in spatial cognition dealing mainly with hand held objects has been borrowed by environmental psychologists to uphold theories in environmental perception.

Research in the area of education has also been useful for the study of spatial skill instruction. Dwyer's (1978) research indicated that realistic drawings may be more distracting to the learner than those with less detail. But how does this relate to the training of spatial skills? Olson and Bialystok (1983) suggested that mental representations used for spatial skills require the explicating of information about objects that is usually implicit (such as an object's basic shape, size or position). They contended that, for spatial skills, a person must develop a "schema" that uses spatial or form information as a part of the structural description of an object. Is it possible that viewing an animation of a solid three dimensional object changing to wire frame form and finally to two dimensions could help to develop such a schema?

Multiple viewpoints of an object have been indicated as important for the formation of accurate spatial representations (Evans, 1980). Active movement by the observer has previously been reported as the most effective means of obtaining spatial information (Mandler, 1962;
Piaget and Inhelder, 1967; Stea and Blaut, 1973). However, studies by Olson and Bialystok (1983) indicated that viewing of film could be equally as effective as direct physical experiences in the teaching of spatial skills. Some kind of movement, however, is still important. In the same study it was reported that subjects who viewed total animation sequences of rotating objects performed better on mental rotations tests than those who only viewed initial and final rotated positions of objects.

Graphics generated by a computer can be manipulated to study the impact of visual experiences. They can be displayed in either solid or wire frame (line drawn) form. Objects to be displayed are plotted on an X, Y, Z, axis system that simulates objects in three dimensional form and perspective when displayed on the screen. The objects can be colored and lighted in many different ways and can be transformed from opaque to transparent with simple commands. The objects can be animated in much the same way as cartoon animation with individual images being captured frame by frame via camera onto 16mm film.

PURPOSE OF THE STUDY

The purpose of this study is to determine the effectiveness of visual presentations, produced by a computer generated graphic animation system, as a teaching tool for spatial skills necessary to produce orthographic drawings. The specific questions to be addressed in this research are:
1. Can exposure of persons to visual presentations produced by a three dimensional computer animation system cause a significant increase in scores in the Vandenburg/Kuse Mental Rotations Test?

2. Can exposure of persons to visual presentations produced by a three dimensional computer animation system cause a significant increase in orthographic drawing skills as measured by an orthographic views test?

3. Will persons exposed to the following order of visual sequences, color/3D, color/2D, wire/3D, wire/2D, score significantly higher on the Vandenburg/Kuse Mental Rotations Test than those exposed to other orders?

4. Will persons exposed to the following order of visual sequences, color/3D, color/2D, wire/3D, wire/2D, score significantly higher on the orthographic views test than those viewing other orders?

5. Will persons exposed to wire frame only for the initial film sequence score significantly higher on the initial mental rotations test than those viewing color only for the initial film sequence?

6. Will persons exposed to both three and two dimensional images in the initial two film sequences score significantly higher on the mental rotation tests than those exposed to three dimensional images only for the initial two film sequences?
SIGNIFICANCE OF THE STUDY

This study will serve two main purposes. 1) It will explore possible uses of three dimensional computer generated graphics animation in an educational setting. 2) It will aid instructors involved in teaching orthographic drafting skills.

Computer generated graphic animation is in a developmental stage. There will continue to be advances in hardware as well as software programs, and it is important for those involved in the educational process to have input as to its usefulness as an educational tool.

The need for spatial skills in the area of housing design is quite evident. Although a person may be able to develop the initial skill of orthographic drawing by imitating examples of others, their design capabilities will be limited. Karlans, Schuerhoff and Kaplan (1969) reported a high correlation between spatial skills and creativity in architects. It would seem that visualization and orientation skills are necessary.

However, children may not be acquiring these skills in the formal educational process. According to Arnheim (1974), spatial skills have long been overlooked by public education. Recent concerns in the area of hemisphere specialization, male-female differences in math related fields of study, and various aspects of computer programming, have brought the study of spatial cognition to the forefront once more. Techniques to instruct for spatial visualization could have far more reaching effects than application only to architectural drawing.
LIMITATIONS

Although results of this research may be applicable to other fields of study, the following limitations must be recognized.

1. The short viewing time of visual treatments could significantly affect the test results.

2. Results are limited only to those visual stimuli chosen to test. They may not be applicable to all computer graphics visuals.

3. Results are also limited to those subjects involved in this study. Generalizations to other samples may not be possible, particularly to other age groups.

ASSUMPTIONS

1. It was assumed that the Vandenburg/Kuse Mental Rotations Test was an adequate test of spatial visualization due to previous use of this test as reported in Chapter 3.

2. It was assumed that the orthographic views identification test provided an accurate measure of orthographic drafting skills of the subjects. This assumption was based on information provided by experts in the area of graphics education at The Ohio State University.
DEFINITION OF TERMS

Computer Graphics: In this paper the term will be used to refer to three dimensional computer generated graphics animation.

Orthographic Projection: A "method of representing the exact shape of an object by dropping perpendiculars from two or more sides of the object to planes, generally at right angles to each other; collectively, the views on these planes describe the object completely" (French and Vierck 1978).

Pictorial Representation: "Designates the methods of projection resulting in a view that shows the object approximately as it would be seen by the eye" (French & Vierck, 1978).

Sectional View: A drawing in which one or more views are used to show an object as if a portion had been cut away to reveal the interior (French & Vierck, 1978).

Spatial Cognition: Internalized reflection and reconstruction of space in thought (Hart and Moore 1973).

Spatial Skill/Spatial Ability: Overtly demonstrable competency in the area of spatial visualization and orientation.
Spatial Orientation: Understanding of the arrangement of elements within a visual stimulus pattern, utilizing the body orientation of the observer (McGee 1979).

Spatial Visualization: An ability to mentally rotate, twist, or invert pictorially presented visual stimuli (McGee 1979).

Vandenberg/Kuse Mental Rotations Test: A group test of three-dimensional spatial visualization based on stimuli used by Shepard and Metzler (1971).

Orthographic Views Identification Test: A group test to measure orthographic drawing skills, created specifically for this research, based on similar tests used by the Engineering Graphics Department at The Ohio State University.

SUMMARY

In this chapter, the necessity of spatial skills for Home Economics students involved in architectural design was discussed. This study researched the use of visual presentations produced by a three dimensional computer graphics animation system for the instruction of spatial skills. Specifically, the skills of mental rotation and orthographic drawing were tested using the Vandenberg/Kuse Mental Rotations Test and an orthographic views identification test as measures. The results offer instructors of multiview graphics a new method of instruction to consider. An exploratory contribution to the
study of three dimensional computer graphics animation systems' use for educational technology and research was also achieved.

This report is divided into four remaining chapters. The review of literature is reported in Chapter Two. Chapter Three presents the research design and procedures, while Chapter Four reports the statistical analysis of the data. Finally, Chapter Five summarizes the findings and presents recommendations for further study.
CHAPTER 2

REVIEW OF RELATED LITERATURE

The review of literature for this topic required examination of research in several fields of study. An attempt has been made to fuse the information from these various areas into a meaningful discussion. The relevant literature is presented under the following subheadings:


SPATIAL COGNITION: DEVELOPMENTAL THEORIES

The study of spatial cognition has its roots in developmental psychology. The most extensive study of the development of spatial cognition was carried out by Piaget and Inhelder (1967). Using a four stage process, the development of the following three aspects of spatial cognition was suggested:

1) cognitive levels: sensorimotor,
   intuitive, concrete operational
   and formal operational
2) types of spatial relationships:
   topological, projective, and
   euclidian
3) systems of reference: egocentric, fixed and coordinated.

The sensorimotor cognitive level occurs prior to Piaget's identification of developmental stages of spatial cognition. The child from birth to about two years operates on a purely perceptual level. At first there is no coordination of vision and grasp. Perceptions are topological: governed by proximity, separation, order, succession, and enclosure. The child's view of the world is strictly egocentric.

Children in Stage 1 (2-3 years) are a part of the intuitive preoperational cognitive level. Prior to this stage, children have accomplished the coordination of vision and grasping. Now, through hand manipulation and motor activity, they are able to develop an understanding of the consistancy of a solid, its size and shape. This is strictly topological, not based on distance, angles, or straightness, but on the properties of being connected or bounded. The child's frame of reference is egocentric. It would not be possible to imagine a viewpoint other than his or her own.

Stage 2 (4-6 years) is somewhat transitional. The child is still at a preoperational cognitive level. Euclidian shapes (circles, triangles, squares, etc.) become recognizable through tactile experiences, and are therefore still topological. There are some
advances in frame of reference. The child begins to realize that there may be other viewpoints. They just aren't imagineable yet.

By Stage 3 (7-12 years), children are at a concrete operational cognitive level. This operational ability allows them to use perspective, linking objects together in a coordinated system. Furthermore, the child is now freed from egocentrism, and is capable of using a fixed frame of reference. The combination of a nonegocentric viewpoint and operational concepts allows the child to perceive projective spatial relationships. Objects or patterns are no longer viewed in isolation, but are considered in relation to a number of points of view. Typically, children in this stage are able to recognize similarities of parallel lines, equal angles and reversed images.

Stage 4 (11-12 years) is characterized by a culmination in the development of both projective and Euclidian spatial relations. The use of projective space begins at an earlier age, whereas Euclidian relationships (the ability to use distance and measurement) do not begin until about the age of eleven.

Euclidian geometry requires a coordinated system of reference which is characterized by a three dimensional axis, most simply defined as left to right, above-below, and before-behind. The child at the formal operational level, is now able to apply this general system of reference to all situations, forming relationships between objects within a three dimensional framework.

To summarize, Piaget and Inhelder indicated that there is a developmental process of spatial cognition that begins at birth and
continues to approximately the age of twelve. During this time, the child advances in cognitive levels from sensorimotor to logical (operational) problem solving. Spatial relationships begin as topological and proceed to projective and Euclidian. Finally, the frame of reference shifts from egocentric to fixed, to a coordinated system.

Piaget identified these stages qualitatively. Flavell (1963), however, suggested that the relationships could be quantitative. He identified frames of reference as being either egocentric or nonegocentric, with quantitative increases within.

Using this idea, Coie, Cosanzo and Farnill (1973) replicated Piaget's study of coordination of perspectives, which required subjects to identify different views of a mountain landscape model. Coie, et al concluded that within the nonegocentric stages there was a unidirectional sequence in the mastery of spatial perspective skills. The sequence began with interposition (hidden areas), moving to aspect, (corner view, back, etc.), and finally culminating in right and left distinctions.

Most research in the cognitive psychology area has supported the developmental process described by Piaget. Some problems arise in the application of the theory to environmental research as will be seen in a later section.

In addition to the developmental characteristics of frame of reference, operational levels and spatial relations, modes of representation was identified by Bruner and Alver (1966) as a developmental process. According to their theory, infants at first
represent information motorically. At a preoperational level they begin to use iconic or picture representations, and finally develop the use of abstract symbols during the operational stage.

Bruner's developmental theory implied a hierarchical pattern of intellectual preferences. Others do not agree. Pavio (1970) reported that mode of representation may vary with the situation. The iconic mode appears to be especially useful for the processing of spatial information; but its usefulness is also dependent upon the experience of the user. Contrary to Bruner, research has also indicated that pictures can be more beneficial than words for memory tasks. (Pavio 1971, Shepherd 1978, Perlmutter and Meyers 1975).

In summary, there is research to support a developmental process of spatial cognition that identifies frame of reference, operational levels, spatial relations, and modes of representations as areas of growth. However, literature to date does not indicate a clear understanding of how adults make use of what has been learned in this developmental process. There is some indication that the nature of the task may dictate the level of spatial cognition at which one operates.

SPATIAL COGNITION: INFORMATION PROCESSING

Although information in the area of cognitive development has been very useful in understanding spatial cognition, it is not complete. It is important to know more specifically how information is received and coded by the brain.
Numerous theories exist as to how visual patterns are recognized and processed. It is assumed that recognition is achieved by comparing a stimulus pattern with memory representations (Larsen and Bundesen, 1975). Stimulus patterns could be encoded by a structural schema, where a complete description is stored as a complex interaction of both visual (iconic) and verbal (symbolic) memory codes (Reed, 1974).

Olson and Bialystok (1983) theorized that spatial concepts are made up of both structural description and meanings. The structural descriptions assigned to an object depends upon; the characteristics of the display, the context in which the display occurs, and the characteristics of the perceiver (such as prior knowledge, stage of development, and expectancies).

The relation between frame of reference and visual processing was also explained by Olson and Bialystok (1983). Objects are initially encoded from an egocentric viewpoint. At that time certain spatial information such as top/bottom, front/back, and left/right is assigned to the display. Objects described as canonical are those that have these features permanently assigned to them. An example would be the telephone. Noncanonical objects, which have no distinguishing orientation features, may temporarily be assigned descriptions that fit a particular situation. Many objects are partially canonical and usually have only a permanently assigned top and bottom, or front and back. Left/right canonical objects are the least common.

Minsky's (1975) ideas are similar. He used the term "frame" to describe a data structure for representing a stereotyped situation. Attached to the frame are "default" assignments. Frames are linked to
a framework system with global space frames determining inter object location in three dimensional space.

The above process, according to Larsen and Bundesen (1975), requires mental manipulating to adjust for differences in; stimulus position, scale, or image characteristics. These adjustments are described by Piaget and Inhelder (1967) as either accommodation (transformations induced in the subject's existing schemata) or assimilation (transformation of the object to correspond with the existing schemata). How these mental manipulations may occur will be discussed in the following section.

ARCHITECTURAL DRAWING AND SPATIAL SKILLS

Mode of representation, frame of reference, spatial relations, and cognitive operational level, can all be considered aspects of spatial cognition that are prerequisites for complex spatial skills. Complex spatial skills necessary for housing design are; visualization, mental rotation, transposition of three dimensional objects to two dimensional paper, and cognitive mapping.

Visualization

Visualization has been described in design terms by McKim (1968) as a means of talking visually to oneself. These visions are described as being seen from the viewpoint of a "mind's eye."

Psychologist have been debating for over a century as to whether images even exist. Most researchers today would agree that people do
have experiences that would seem to be mental images, but these images are not concrete pictures. Pylyshyn (1978) suggested that what a person "sees" is not an image but a set of mechanical operations; and that the image metaphor needs to be replaced by a fine detail processing model. Further, he stated that a third nonexternalizeable mode of representation must exist that allows mental communication between words and images.

Other researchers do not agree with Pylyshyn. Kosslyn and Pomerantz (1977) described mental images as quasi pictural spatial entities, where perception is not the inspection of an internal screen but a processing of sensory information.

Using scanning to assess whether distances in three dimension are represented in images, Pinker and Kosslyn (1978) found that time to scan between two objects was highly correlated with the three dimensional distance between objects. Their research indicated a possibility that an internal three dimensional medium and a set of visual pattern recognition processes that operate upon it, exist.

Other research by Kosslyn (1975, 1978) revealed that visual images have only a limited spatial screen available for constructing mental images. This screen is more horizontal than vertical, slightly rounded, with fading vision around the edges. As subjects envisioned animals walking towards them the vision would overflow the screen as would happen in an actual situation. Larger animals would overflow at a farther distance than smaller ones. Detail of images also varied. It took subjects longer to evaluate smaller and more complex objects
than larger, simpler ones. There appeared to be a limit as to the amount of detail possible to activate on the screen.

Mental Rotations

The ability to mentally rotate objects in three dimensional space is an extension of simple visualization skills. One of the findings of Shepard's research (1978) with mental rotation of three dimensional objects, was that there seemed to be intermediate states in the internal process of rotation that had a one to one correspondence to intermediate orientations of the external object. In other words, persons were not able to immediately recognize that two objects were alike if their rotations were different. Shepard and Metzler (1971) reported that subjects said they had to mentally rotate one object to check it against the other. This was substantiated in their research by the fact that the time required to recognize the "alikeness" of two objects was found to be a linearly increasing function of the angular difference in their portrayed orientation. Research by Olson and Bialystok (1983) support these findings.

Frame of reference becomes an important issue when considering mental rotations. Piaget and Inhelder (1967) reported that mistakes in frame of reference in children were usually of an egocentric nature. From this they concluded that it was only when a child was able to leave the egocentric stage, and imagine another viewpoint that advances in spatial relations could be made. This has been interpreted to mean that once a person can utilize a coordinated system of reference, that they would no longer use egocentric. (see Siegel and White, 1975; Hart
and Moore, 1973). However, Pufall and Shaw (1973) claims that through development one does not lose the need for an egocentric viewpoint, but merely learns to coordinate it with other frames of reference.

The type of object being rotated contributes to the ease or difficulty in establishing frame of reference. Canonical objects as described by Olson and Bialystok (1983) are easier to rotate than noncanonical ones. Pufall and Shaw (1973) found that ten year olds continued to use a self referent (egocentric) system when topological codes were absent in displays.

Outside frameworks may also be used to code objects, and therefore aid in mental rotations. The outside framework becomes especially important when the viewer is rotating about the object rather than the object rotating (Huttenlocher and Presson, 1979). Egocentric coding of noncanonical objects is no longer useful if the viewer is constantly moving, causing the orientation of front/back, etc. . . to be constantly changing.

Transformation of Objects to Two Dimensions

Transformation of three dimensional ideas into a two dimensional context, in the form of orthographic drawings, is another complex spatial skill. As identified by Stea and Blaut (1973), the skill not only requires a person to be able to mentally rotate an object to another plane, but also change its scale and abstract the object into semi iconic signs. Their research indicated that children are able to begin to learn these skills (even though they are not at the appropriate Piagetian stage), through toys that model real situations
such as small houses, or cars. Ninio (1979) addressed the 2D-3D transpositions as a problem to researchers. Using drawings as representations of a person's spatial abilities would assume that the subject has Euclidian as well as topological cognitive strategies.

Cognitive Mapping

A final necessary skill for the designer of interior environments is cognitive mapping. It has been described by Downs and Stea (1973, p. 9) as "a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in his everyday spatial environment." Although the term "map" is used they contend that it is not really a map but a functional analogue, indicating a process rather than product. Kuipers (1982) concurred, stating that the map like metaphor gives only half of the picture. Cognitive maps represent: 1) procedures for following routes, 2) topological network descriptions, and 3) metrical descriptions consisting of relative position vectors. He contended that this information is retrieved separately and therefore a computational model would better describe the process than a "map".

Similar to arguments on image processing, Evans, Marrero and Butler (1981) have organized research on cognitive map storage into two camps:

1) associated networks based on abstract representation
2) analogical view where mental representations
    are rough isomorphic images.

The associated network theory was described by Kaplan (1973) as a
schemata, based on efficient perception, where a person can identify a
current situation in a way that capitalizes on past regularities. This
demands a structure that must not require that all features, or any
particular feature is present. Kossylin (1975) and Shepard's work
(1978) described under visualization has been used to substantuate the
analogue view.

In summary, the literature at this point does not seem to agree as
to the exact method of coding or even if everyone codes in the same
manner. There is some evidence however to indicate that regardless of
how the image is formed, persons do experience the sensation of
something similar to a mental image. Furthermore persons can mentally
imagine objects rotating and changing in form. These "mental skills"
are necessary before one can produce orthographic drawings.

ENVIRONMENTAL SPACE

In applying basic theories of spatial cognition, environmental
psychologist have had some problems. To understand these problems one
must first examine the relationship one has with the environment.

Evans (1980) described this relationship as one in which the
observer is an interactive part of the environment, not a passive
observer of stimulus objects. The environment surrounds the observer
and is viewed from multiple vantage points as it is explored.
The observer uses such cognitive activities as, expectancies, attitudes, symbolic elaboration and transformations of the world of reality to mediate and modulate the impact of the environment (Kates and Wohlwill, 1966). These expectancies and attitudes are based on personal idiosyncracies and cultural traditions which include geographical, architectural, and social aspects (Canter, 1977).

The environmental orientation experience was identified by Norberg-Shultz (1971) as a process of five sequential concepts as outlined below:

1. pragmatic space of physical action - integrates man with his natural organic environment
2. perceptual space of immediate orientation
3. existential space - a stable image which includes social and cultural influences
4. cognitive space - how a person thinks about the space
5. logical space - abstract, a tool to describe the space to others.

Just how these personal schemata might influence a person's understanding of his environment was researched by Cox and Zannaras (1973). They found that in sketch map drawings, persons tended to place familiar places closer together.

The nature of the environment as well as the individual have control over what is perceived. As Lynch stated, "The quality of the physical
object (shape, color, arrangement) . . . facilitates the making of vividly identified, powerfully structured, highly useful mental images" (Lynch, 1960, p. 9). Saddler and Burroughs (1978) found that recognition of architectural forms was strongly related to the distinctiveness of the building.

How environmental information is processed is based on the schemata a person has developed. Lynch (1960) suggested that people have a general environmental schemata based on five categories listed below:

- **paths**: channels along which one moves
- **edges**: barriers or boundaries
- **districts**: medium to large sections
- **nodes**: points, strategic spots that can be entered
- **landmarks**: external points that cannot be entered

The results of the above process is the formation of an environmental cognitive map. Just as psychologists have questioned the encoding and storage of cognitive representation in basic research, environmental psychologists also have questions.

When a person experiences a new environment, what is noticed first, landmarks or the path? Siegel and White (1975) claimed that there is a developmental model of spatial representation. Persons first notice landmarks. These landmarks are then used to learn a route, in a point by point fashion. The landmarks and routes are organized into small clusters with good internal organization, but poorly connected to one another. Finally, survey representation occurs with routes being coordinated within an overall frame of reference.
Using the developmental model for frame of reference from egocentric to fixed to coordinated, Hart and Moore (1973) determined that a person would use route (egocentric) information first, then proceed to landmarks as reference points (fixed) and finally develop a framework to interrelate positions, (coordinated). It is possible that perceptions may vary depending upon the situation or persons. It is also possible that both landmarks and paths are perceived simultaneously.

The field of environmental cognition is relatively new. Research and theories have relied heavily on studies in the areas of developmental and experimental psychology. Most of Piaget and Inhelder's test (1967) were conducted with hand sized items. Is it possible to make generalizations to include large scale environments as well? Herman and Siegel (1978) found that walking through a large scale model significantly increased the accuracy of a child's cognitive map. Motor experience was not possible with Piaget's research.

Evans (1980) also noted that the hand held model offers a different visual perspective than the large scale environment. Also, there is not as much egocentric responding to an object that can be turned around in the hand.

Although Piaget and Inhelder (1967) concluded that by age 12, children are capable of using coordinated frames of reference, studies have indicated that in large scale environments, adult subjects used their home or self centered frame of reference more than NSEW for orientation. (Lewis, 1972; Galley, 1958). Siegel (1982) concluded
that although the egocentric and fixed frame of references would be considered primitive by Piaget, in large scale environments they may be more efficient.

Previous experiences by the subject is another factor that has generally been ignored by researchers. Stea and Blaut (1973) found that children were able to use aerial photos as maps, identifying houses and other familiar items. This feat required the rotation to another plane, reduction in scale and abstraction of objects to semicionic signs, (capabilities that they were not supposed to possess according to Piaget). Stea and Blaut concluded that this ability on the part of the children may have been due to previous experiences in toy play with model cities.

Evans (1980) also reported that previous experiences with sketch maps enhanced the accuracy and complexity of children's hand drawn maps.

Finally there has been extensive criticism of the use of sketch maps to indicate a person's spatial abilities, particularly those of children (Spencer and Darvizeh, 1981). Liben, Moore, and Goldbeck (1982) found that children were able to arrange the furniture in their classroom accurately, although they were not able to express the same knowledge on paper. Ninio (1979) also indicated that the activity of drawing has inherent spatial organization. Every drawing, simply by the movement of the pencil is topological. The drawing becomes a separate entity with its own idiosyncrasies. The first lines drawn on the paper have been found to effect the rest of the representation (Goodnow 1977).
It is clear that our understanding of environmental spatial cognition is not complete. Although Piaget's developmental theories are still useful for large scale environmental studies, there is also an indication that people may not always utilize their full developmental capacities. In many cases it may not even be efficient to do so. In environmental situations persons may find use of topological relationships and egocentric or fixed frames of reference quite satisfactory. It is only when they are called upon to either represent or see a representation of their environment in another scale or in another dimension that they are forced to use Euclidian relationships and nonegocentric frames of reference.

EDUCATIONAL IMPLICATIONS

Research in both Environmental and Cognitive Psychology have reported improvements in spatial skills after training. In experiments by Siegel and Schadler (1977) with young children and their classroom environment, it was found that experience in an environment significantly enhanced the understanding of Euclidian relationships of that environment, but not projective or topological. Evans, Marrero, and Butler (1981) found that experience had a linear relationship with development of frame of reference. Further they determined that not only the amount of experience but the kind of setting exploration determined spatial understanding of that setting. When settings were learned from multiple perspectives as opposed to one perspective only,
knowledge of spatial relationships in that setting could be flexible and not perspective bound (Evans and Pezdek, 1980).

Evans and Pezdek (1980) theorized that as the number of viewpoints associated with an object increases, greater restriction is placed on the possible locations it can occupy. This leads to increased accuracy in placement.

In order for a person to experience multiple viewpoints, some movement must take place. As explained by Stea and Blaut (1973), increasing dimensional information is available through movement, and therefore, the greater the active movement a person experiences, the more opportunities there will be to learn to coordinate perceptions with movement.

The mobile experience could take three different forms as described by Spencer and Darvizeh (1981): 1) active movement by the observer through stationary space, 2) film or television with a stationary observer and a mobile environment, 3) object manipulation - observer control over a mini environment.

Active movement by the observer would appear to be the most effective means. Mandler (1962) reported that actions and movements repeated endlessly become transformed into spatial images. Cohen and Weatherford (1981) tested children's knowledge of a room sized environment after either walking through the environment or watching the experimenter walk through. Their results indicated that actual path walking, and the amount of that experience was required to integrate multiple points of view. However, they further concluded that if time was limited, it would be better spent with a small set of
views rather than a path experience which distributes that limited time over a greater set of views.

Recently studies using film to simulate a multiview experience have reported different results. Salomon (1979) stated that film is a good instructional medium for spatial cognition because it can depict continuous spatial transformation as the mind does. Olson and Bialystok (1983), using objects similar to those in the Vandenburg/Kuse Mental Rotations Test, found that mediated rotations were nearly as effective in teaching mental rotation as actual experiences.

Not only the experiences of the observer, but characteristics of the environment have educational implications. Three areas have been researched; the presence of barriers, number and type of landmarks, and vertical/horizontal spaces.

If barriers are present in an environment, distortion in representation will result. Sherman, Croxton, and Smith (1979) found that barriers caused short distances to be overestimated and long distances to be underestimated. These distortions could be minimized with an extended amount of time in the environment (Cohen and Weatherford, 1981).

The distinctiveness of landmarks was found to be a factor in the ability of preoperational children's ability to learn spatial locations (Acredolo, Pick and Olsen, 1975). Although the researchers felt that familiarity can directly aid spatial cognition by increasing an individual's sensitivity to the meager differences that may exist, it was not found to be significant, whereas the number and type of landmarks was.
Finally there is a difference in persons' abilities to understand vertical and horizontal spaces. As has already been reported, Kosslyn (1978) found visual images to be more horizontal than vertical. This information coincides with Fisher (1968) who reported that monocular visual limits are 120 degrees in the vertical and 150 horizontal. Person's visual experiences in general seem to be more horizontal than vertical, due to environmental features. Hardwick, McIntyre and Pick (1976) found in interviews of children and adults, about their homes, that children could give better information about what was on the same floor than in a vertical direction. Adults tended to overestimate vertical distance more often than horizontal.

Although the thrust of this research is visual, it is important to note that spatial cognition is multimodal and in some way relies on all senses for input. Sturm and Jorg (1981) studied children's information processing of television. They found that verbal information, even when the pictoral seemed obvious, improved task performance.

Reports of formal training of spatial cognition are varied. In the area of visualization training McKim (1968) suggested that it is possible to sharpen the "acuity of the mind's eye" through exercise. His exercises include first a state of relaxed concentration, then practices of mentally distorting familiar objects, and visual brainstorming. Sommer (1978) suggested that if visual aids are to be used that the pace of programming should be slow with periods of silence and blank screen. Gibson (1953) reported that improvement in perceptual judgement is a function of frequency of practice, with feedback of correctness being extremely important.
Visualization training has been used by Peticlerc (1972) to improve reading abilities of young children. Her program used tactile kinesthetic exercises to improve visualization.

Tests in spatial visualization are available and have been used to determine improvement of spatial cognition after training. The Spatial Visualization Abilities Test (SVAT) was used to determine the effects of visualization training on fourth grade and early adolescent boys and girls. Results indicated that at the early adolescent age, boys significantly improved on the SVAT after training, but girls did not (Smith and Litman, 1979). Instruction at the fourth grade level did not differentially effect boys and girls (Smith and Schroeder, 1979).

At the adult level Thurston's Paper Folding Test was used to determine the effect of training and cognitive level on spatial abilities (Hill and Obenauf, 1979). Their results indicated that those at a formal operational level improved to a greater extent than those at a concrete operational level. Baltista, Talsm and Wheatly (1973) found similar results in testing preservice elementary teachers before and after a geometry course. Using the Purdue Spatial Visualization Test: Rotation, they found that cognitive development was a better predictor of the geometry course grade than spatial visual ability, but both were important.

The Vandenburg/Kuse Mental Rotation Test was used in research reported by Olson and Bialstok (1983) to test person's spatial visualization skills after training. Their research indicated that subjects with only twelve minutes of instruction scored significantly higher than the control group.
It appears that research in the area of visualization training has been slight and varying in scope. Perhaps the most important results have been that training can improve spatial skills, and mediated experiences can be nearly as effective as actual experience. Evidence is lacking, however, as to what specific techniques may be most effective and efficient for this task.

SUMMARY

This review of literature has been an attempt to tie together research from a variety of related fields of study including, Educational Technology, Educational Psychology, Architecture, Environmental Design, and Art Education. It is recognized by this researcher that one must be cautious when applying results of research in one area to that of another. With this understanding in mind, the following points were identified as a basis for developing the rationale for this study.

1. Spatial cognition is a developmental process. In order for persons to make full use of spatial skills, they should be capable of using formal cognitive operations, Euclidian spatial relationships, a coordinated frame of reference, and iconic modes of representation.
2. Persons develop structural schema which are used to recognize and process visual patterns. The nature of that structural schema will determine what is actually perceived.

3. Although there is debate as to how images are coded, persons do experience the sensation of something similar to a mental image which can be mentally rotated and changed in form. Such mental skills are necessary before one can produce orthographic drawings.

4. In the "daily living" perceptions of large environments, persons are not normally required to use the highest levels of spatial cognition, rather relying on topological relationships and egocentric or fixed frames of references as cues. Therefore, unless specifically trained, persons may not have a structural schema for environmental perception that includes Euclidian relationships or coordinated frames of reference.

5. Training can improve spatial skills; and mediated experiences can be nearly as effective as active experiences.
CHAPTER THREE
RESEARCH DESIGN AND PROCEDURES

Spatial skills necessary for housing design and analysis are sometimes lacking in Home Economics college students in the housing area. Research has indicated that a person's spatial skills can be improved through training (Hill and Obenauf, 1979; Olson and Bialystok, 1983). However, specifics as to what techniques are most effective have not been determined. A major purpose of this study was to investigate the effects of viewing selected visual presentations, produced by a three dimensional animated graphics system on the development of spatial skills. Changes in scores on the Vandenberg/Kuse mental Rotations Test, and an orthographic views identification test were used to determine these effects.

The procedure followed in this study is presented as follows: identification of the variables, pilot studies, subjects setting, research design, and, data collection and analysis.
IDENTIFICATION OF VARIABLES

The independent variable was comprised of a set of different visual treatments that were produced on a computer. The dependent variable included: 1) spatial ability scores as measured by the Vandenburg/Kuse Mental Rotations Test, and 2) orthographic drawing skills as measured by an orthographic views identification test.

Visual Treatments

The medium of three dimensional computer graphics animation was chosen to produce selected visual stimuli for the instruction of spatial skills. Computer generated graphics offers several advantages. From an instructional viewpoint it would seem that the type of visuals produced by a computer could be useful in helping persons to develop a schema or structural description (see Olson and Bialystok, 1983) that includes the orthographic features of an architectural interior environment.

This type of visual presentation could also be produced by traditional cartoon animation techniques, however, the computer offers more efficiency, versatility and control. After initial programs or objects are produced, changes can be made fairly easily. For example, a program written to animate the rotation of the data representing a chair could be used to animate the data base of any object by simply changing the name of the datafile used. Furthermore, the color, scale, position, or rotation of an object can be manipulated to achieve specific control over visual stimuli to be tested.
The graphics for this research were produced on a computer with resident software capable of producing full color as well as wire frame monochromatic images. Objects were animated in much the same way as cartoon animation with individual images being captured frame by frame via camera onto 16mm film. All productions were accomplished with the supervision of the Computer Graphics Research Group under the direction of Charles Csuri, The Ohio State University, and John Belland of the College of Education, The Ohio State University.

Four animation sequences were used to present the visual stimuli. Three objects were used in all four animations: a staircase against a wall, a house and a kitchen cabinet grouping (Figure 1).

![Staircase, House, Kitchen Cabinets](image)

Pictoral View of Treatment Objects

**Figure 1**

A description of each sequence follows:

**Sequence A:** Each object, solid color form, rotated 360 degrees on the "Y" axis. Each object, solid color form, rotated on the "Y" axis to a side view. Each object, solid color form, rotated on the "X" axis to a top view.
Sequence B: Each object, solid color form, rotated on the "Y" axis to a side view and then changed from three dimensions to two. Each object, solid color form, rotated on the "X" axis to a top view and then changed form three dimensions to two.

Sequence C: Each object, wire frame form, rotated 360 degrees on the "Y" axis. Each object, wire frame form, rotated on the "Y" axis to a side view. Each object, wire frame form, rotated on the "X" axis to a top view.

Sequence D: Each object, wire frame form, rotated on the "Y" axis to a side view and then changed from three dimensions to two. Each object, wire frame form, rotated on the "X" axis to a top view and then changed from three dimensions to two.

Five seconds of blank film separated each segment of the rotation sequence. All treatments were visual only, no audio accompanied the films.

The four animation sequences described above were presented to subjects in varying order to create the four treatment groups outlined below.

Group 1: viewed no films
Group 2: viewed C D A B
Group 3: viewed C A D B
Group 4: viewed A B C D
To assure attentiveness to the task, subjects were required to list
the three objects seen on the films as a final question on the personal
interview sheet.

Selection and Development of Test Instrument

Subjects were tested for; improvement of spatial cognition, and
the ability to identify orthographic views of architectural images.

The Vandenburg/Kuse Mental Rotations Test was used to test spatial
cognition (Appendix A). The test was constructed from figures used by
Shepard and Metzler (1971) in a chronometric study of mental imagery.
Each test item consisted of a criterion figure and four alternative
figures, two of which were the same as the criterion and two incorrect.
The two correct alternatives were rotated versions of the criterion
figure.

The test as developed by Vandenburg and Kuse consisted of twenty
problems. For this study five problems were used for a pretest, and
ten problems for each of four post-tests.

The reliability of the test, based on 3,268 adults and
adolescents, aged 14 years and older, was .88 using the
Kuder-Richardson Formula 20 (Wilson, DeFries, McClean, Vandenburg,
Johnson, and Rashad, 1975). Correlations with other tests of spatial
relations ranged from r = .36 to r = .68 (Kuse as reported by McGee, 1981).
Vandenburg and Kuse (1978) reported that the Mental Rotations Test
compared well with other tests of spatial ability, especially tests of
spatial visualization. For further information on reliability see Park
(1975), Bouchard and McGee (1977), Wilson et al. (1975), and Kuse
In order to test orthographic drawing ability, an orthographic views identification test was developed. The test (Appendix A) consisted of six problems. Each problem contained a pictoral view of an architectural image and five possible orthographic solutions for front, side, and top views. The subject was to place an "X" in the box in which all three views were orthographically correct. If none of the five suggested representations were correct, the subject was told to place an "X" by the pictoral view.

Three of the architectural images used for the test were the exact images shown on the treatment films. The others were new images.

The reliability of the orthographic views test, based on 20 Home Economics students at The Ohio State University, was .91 using the Kuder-Richardson Formula 21.

PILOT STUDIES

Two pilot studies were conducted to develop some experience in the use of testing procedures and general format for showing the films.

The first pilot study involved the administering the mental rotations test and orthographic views tests only. No treatment films were shown. The sample consisted of 10 Home Economics students enrolled in classes Autumn Quarter, 1984. Five students were given twenty mental rotations problems to complete in five minutes, and then six orthographic views problems to also complete in five minutes. A second group of five students was given the same tests with unlimited time.
It was determined from this initial pilot test that five minutes was not enough time to complete twenty problems. Only one student completed more than ten problems within this time constraint. Furthermore, time was an important factor in test scores. Those who were given unlimited time scored higher than those on limited time.

Time was not as important a factor for the orthographic views test. Scores for both the timed and untimed group were similar. Five minutes appeared to be a reasonable amount of time to complete this test. Four of the five students in the untimed group completed the orthographic views test within the five minute limit.

Subjects for the second pilot study were also selected from Home Economics classes, Autumn Quarter, 1984. A shortened form of the final data collection procedure was used. Five subjects were exposed to animated wire frame three dimensional views of objects, while a second treatment group of five students viewed wire frame objects in both three and two dimensions.

The Vandenburg/Kuse Mental Rotations Test was given as a pretest, and as post-tests once at the end of each film sequence. The orthographic views test was given as a final post-test.

The second pilot study helped to establish time constraints of data collection. It was determined that one full 50 minute class period, plus 30 minutes of another class period would be necessary to complete the testing. Furthermore, the 16 mm film projection system was determined as an adequate way to present the visual treatments.
SUBJECTS

Students enrolled in Home Economics classes at The Ohio State University, Winter Quarter, 1985 were the subjects for this experiment. Instructors for Home Economics 290 (Home Economics as a Profession) and Textiles and Clothing 270 (Clothing Selection and Costume Design) were asked if they would allow classroom time to be used for students to participate in this study. Student participation was justified in Home Economics 290 by the fact that one course objective was to introduce students to research in Home Economics. Students enrolled in Textiles and Clothing 270 would find it necessary to use spatial skills as a part of the course. It was therefore hoped that the research experience would be helpful to them.

These two classes were chosen by the experimenter because of their large enrollment numbers, (81 and 94) and the fact that both courses were generally taken by beginning Home Economics students. This last factor helped to insure that few of the subjects would have been exposed to drawing or design courses that would affect the research results.

Students in each class were randomly divided into two subgroups, with each subgroup becoming one of the four treatment groups. Because the experiment required two class periods, there were some problems with absences. Either students were not present on the first testing day and present the second, or the reverse. Students who were present only one day or who had had extensive previous drawing experience were
not used. Sample sizes for each treatment group ranged from 24 to 27. Table 1 reports the characteristics of the sample.

Ninety-four percent of the subjects were females. Furthermore, the majority of the subjects were textiles and clothing majors. This factor was due to large numbers of textiles and clothing majors in the college, as well as having used Textiles and Clothing 270 for sample gathering. Neither factor was of concern for this particular study since the major intent of this research was investigate spatial learning. The findings from this study might be presumed to help Home Economics students.
<table>
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FR&HD  Family Relations and Human Development
HEDUC  Home Economics Education
HMG&HS Home Management and Housing
HNUTR  Human Nutrition
TX&C   Textiles and Clothing
OTH    Other
SETTING

The normal classroom for the course was used for the introduction to the research and for one of the treatment groups. The second treatment group for each class was moved to another classroom nearby. Classrooms varied as to size and seating arrangements for students. The classrooms either had tables and chairs or chairs with sidearm desks. In every case all subjects faced the same direction and viewed films on a screen located in the front of the room. The size of the image remained relatively constant in all cases. The time of day in which the treatments were administered varied in accordance with university scheduled meeting time of each course.

Time span between the two days of treatment varied also. Groups A and B experienced a one week wait between treatments. Group C, received treatments on two consecutive days, while Group D had a one day delay.

RESEARCH DESIGN

In this section, the research hypotheses will be identified first, and then the experimental arrangements will be described.

Hypotheses

The following six hypotheses, stated in the null form were tested in this study:
H01: Persons exposed to visual presentations produced by a three dimensional computer graphics animation system will not score significantly higher on the Vandenburg/Kuse Mental Rotations Test than the control group.

H02: Persons exposed to visual presentations produced by the three dimensional computer graphics animation system will not score significantly higher on the orthographic views test than the control group.

H03: Persons exposed to the following order of visual sequences, color/3D, color/2D, wire/3D, wire/2D, will not score significantly higher on the Vandenburg/Kuse Mental Rotation Test test than those viewing other orders.

H04: Persons exposed to the following order of visual sequences, color/3D, color/2D, wire/3D, wire/2D, will not score significantly higher on the orthographic views test than those viewing other orders.

H05: Persons exposed to wire frame images only for the initial film sequence will not score significantly higher on the Vandenburg/Kuse Mental Rotations Test than those who viewed color images only for the initial film sequence.

H06: Persons exposed to both three and two dimensional images in the initial two film sequences will not score significantly higher on the
Vandenburgh/Kuse Mental Rotations Test than those who viewed three
dimensional images only for the initial two film sequences.

Experimental Arrangement

A form of a counterbalanced design (Campbell and Stanley 1965),
was used for this study. The design as presented in Figure 2 allows
all subjects to experience all treatments, but in differing order. The
design included an initial pretest of mental rotations and then a
post-test of mental rotations after each treatment. A final post-test
in orthographic skills was also included.

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1 Mental Rotations Test
2 Orthographic Views Test
XA Color/3D Treatment
XB Color/2D Treatment
XC Wire/3D Treatment
XD Wire/2D Treatment

Counterbalanced Experimental Design

Figure 2
DATA COLLECTION AND ANALYSIS

Data collection is described for one group. The same procedure applied to all, with only the rotation of the treatments differing.

The data collection for each group took place in two sessions on different days.

Day 1: Subjects were first given a personal information sheet to complete (Appendix A). They were then given a fifteen minute lecture on the purpose of the research project and a definition of orthographic representation. The lecture included illustrations of orthographic projections shown with the use of an overhead projector (Appendix C). Subjects then adhered to the following routine:

- Mental Rotations Pretest 2.5 minutes
- Visual Presentation 1 6 minutes
- Mental Rotations Posttest 5 minutes
- Visual Presentation 2 4 minutes
- Mental Rotations Posttest 5 minutes

Day 2:
- Visual Presentation 3 6 minutes
- Mental Rotations Posttest 5 minutes
- Visual Presentation 4 4 minutes
- Mental Rotations Posttest 5 minutes
- Orthographic Views Test 5 minutes
During the blank film sections between images, the subjects were instructed to close their eyes and attempt to mentally recreate what they saw on film.

The Statistical Analysis System (SAS) PROC GLM MANOVA was used to calculate the test statistics. The MANOVA allowed all repeated test scores of the Vandenberg/Kuse Mental Rotations Test and the Orthographic Test to be analyzed simultaneously. Therefore, any interaction between the two different tests and influences of the repeated measure was accounted for. A post hoc Fisher's LSD was used to determine sources of significance of difference for each test found to be significant in the MANOVA.

SUMMARY

The stated null hypotheses, research design and data collection and analysis were the major subjects of this chapter. 101 Home Economics college students viewed films for spatial skill instruction and were then tested using the Vandenberg/Kuse Mental Rotation Test and a self designed orthographic views test. A form of counterbalanced design was employed in order than each treatment group might experience all treatment films but in differing order. The Statistical Analysis System (SAS) PROC GLM MANOVA was employed to analyze the data, with a post hoc Fisher's LSD followup. A discussion of the pilot studies, subjects and setting was also included in this chapter.
CHAPTER FOUR

ANALYSIS OF THE DATA

The purpose of this study was to discover whether animated views of objects rotating and changing from three to two dimensions could improve a person's spatial skills and/or orthographic drawing skills. To determine this, 101 Home Economics college students were divided into four treatment groups. Three of the groups were shown four animated sequences in differing orders and tested after each with the Vandenburg/Kuse Mental Rotations Test. An orthographic views test was given after the last mental rotation test. The fourth treatment group operated as the Control; taking the tests, but not viewing the films.

The Statistical Analysis System (SAS) PROC GLM MANOVA (Treatment Groups X Rotation Test 1 X Rotation Test 2 X Rotation Test 3 X Rotation Test 4 X Orthographic Test) was employed to determine significant differences among the treatment groups. A post hoc Fisher's LSD analysis was used to determine sources and significance of differences for each test found significant in the MANOVA.

The analysis of the data is reported in two sections. In the first section, the spatial skill level of the sample as determined by the pretest (Vandenburg/Kuse Mental Rotation Test) is discussed. Section two reports the statistical analysis of the four mental
rotations post-tests and the orthographic views post-test as it relates to each stated hypothesis.

PRETEST

Although subjects were randomly assigned to treatment groups within the two Home Economics classes used to draw the sample, there was no way to control the nature of the students who chose to enroll in these courses. Therefore, a mental rotations pretest was administered to all subjects to determine the spatial skill equivalency of the treatment groups. Table 2 contains the means and standard deviations of each group's mental rotation pretest scores.

A total score of 10 was possible on the pretest. Means would seem to indicate a need for improvement in mental rotation skills. However, no direct comparison with Vandenburg/Kuse Mental Rotation Test scores administered by other researchers is possible due to a differing format and time allotment used in this study.
Table 2

Group Means and Standard Deviations for Vandenburg/Kuse Mental Rotation Pretest

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An analysis of variance was employed on the pretest scores to determine any significant differences in spatial skill abilities between the four treatment groups. Table 3 contains a summary of that analysis.
Table 3

ANOVA of Pretest by Treatment Groups

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<td>16.4497</td>
<td>5.62</td>
<td>.0015*</td>
</tr>
<tr>
<td>GROUP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERROR</td>
<td>283.8191</td>
<td>97</td>
<td>2.9260</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>333.1683</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p<.01

As indicated by the table, differences in groups' pretest scores are significant at the p<.01 level. In order to analyze treatment group effect on posttest scores, means of post-test scores were adjusted to account for these pretest differences (Table 4).
<table>
<thead>
<tr>
<th>TEST</th>
<th>TREATMENT GROUP</th>
<th>N</th>
<th>MEANS</th>
<th>STD ERR MEANS</th>
<th>ADJUSTED MEANS</th>
<th>STD ERR MEANS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONE</td>
<td>1 (C)</td>
<td>24</td>
<td>13.2917</td>
<td>.5399</td>
<td>14.0517</td>
<td>.6476</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>27</td>
<td>12.0741</td>
<td>.7278</td>
<td>12.1603</td>
<td>.5819</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>25</td>
<td>12.2800</td>
<td>.6494</td>
<td>11.7306</td>
<td>.6209</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>26</td>
<td>13.1923</td>
<td>.6026</td>
<td>13.0465</td>
<td>.6084</td>
</tr>
<tr>
<td>TWO</td>
<td>1 (C)</td>
<td>24</td>
<td>11.7083</td>
<td>.5630</td>
<td>12.2672</td>
<td>.6862</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>27</td>
<td>13.2222</td>
<td>.7188</td>
<td>13.2856</td>
<td>.6165</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>25</td>
<td>11.6400</td>
<td>.7115</td>
<td>11.2360</td>
<td>.6579</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>26</td>
<td>13.4231</td>
<td>.6304</td>
<td>13.4789</td>
<td>.6447</td>
</tr>
<tr>
<td>THREE</td>
<td>1 (C)</td>
<td>24</td>
<td>13.8333</td>
<td>.7164</td>
<td>14.3650</td>
<td>.7143</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>27</td>
<td>14.4444</td>
<td>.7068</td>
<td>14.5048</td>
<td>.6418</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>25</td>
<td>15.1200</td>
<td>.6009</td>
<td>14.7357</td>
<td>.6848</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>26</td>
<td>14.6800</td>
<td>.6102</td>
<td>14.4887</td>
<td>.6711</td>
</tr>
<tr>
<td>FOUR</td>
<td>1 (C)</td>
<td>24</td>
<td>13.1667</td>
<td>.2736</td>
<td>13.7694</td>
<td>.6729</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>27</td>
<td>14.3333</td>
<td>.7586</td>
<td>14.4017</td>
<td>.6046</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>26</td>
<td>14.1538</td>
<td>.7353</td>
<td>14.2332</td>
<td>.6322</td>
</tr>
<tr>
<td>ORTHO</td>
<td>1 (C)</td>
<td>24</td>
<td>02.1667</td>
<td>.2736</td>
<td>02.1326</td>
<td>.3221</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>27</td>
<td>02.7778</td>
<td>.2939</td>
<td>02.7739</td>
<td>.2894</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>25</td>
<td>03.0000</td>
<td>.3317</td>
<td>03.0246</td>
<td>.3088</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>26</td>
<td>03.5769</td>
<td>.3097</td>
<td>03.7323</td>
<td>.3026</td>
</tr>
</tbody>
</table>

* A total possible score of 20 was possible on the post-tests.
SUMMARY OF HYPOTHESES

The SAS PROC GLM MANOVA was employed first to determine if any significant effects due to treatment groups occurred. Table 5 reports the overall MANOVA results.

Table 5
MANOVA of Post-tests by Treatment Group Using Wilks' Criterion

<table>
<thead>
<tr>
<th>Sources</th>
<th>DF</th>
<th>F</th>
<th>p&lt;\text{F}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>15</td>
<td>2.40</td>
<td>.0029*</td>
</tr>
<tr>
<td>Error</td>
<td>257</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* significant p<.05

All differences in the analysis are based on corrected group means according to pretest scores. A report of the analysis as it pertains to each hypothesis follows.
H01: Persons exposed to visual presentations produced by a three-dimensional computer graphics animation system will not score significantly higher on the Vandenburg/Kuse Mental Rotations Test than the control group.

In order to test this hypothesis it was necessary to examine the differences in mental rotation test scores after each treatment. If the treatment was effective, differences might occur immediately, or be attributed to an accumulative effect which would not be indicated until the final mental rotation test.

A summary of the MANOVA data for analyzing group differences is reported in Table 6. Significant group differences were found for both Test 1 and Test 2, not for Test 3 and Test 4. Table 7 reports the MANOVA for Test 1. Table 8 reports the MANOVA for Test 2. Table 9 reports the MANOVA for Test 3 and Table 12 reports the MANOVA for Test 4.
<table>
<thead>
<tr>
<th>Test</th>
<th>DF</th>
<th>F</th>
<th>p&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>3</td>
<td>2.58</td>
<td>0.0569*</td>
</tr>
<tr>
<td>Two</td>
<td>3</td>
<td>2.63</td>
<td>0.0539*</td>
</tr>
<tr>
<td>Three</td>
<td>3</td>
<td>0.05</td>
<td>0.9810</td>
</tr>
<tr>
<td>Four</td>
<td>3</td>
<td>0.17</td>
<td>0.9125</td>
</tr>
<tr>
<td>Ortho</td>
<td>3</td>
<td>4.32</td>
<td>0.0068*</td>
</tr>
</tbody>
</table>

*significant p<.05
Table 7
MANOVA of Test 1 by Treatment Groups

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sums &amp; Partial Sums of squares</th>
<th>Mean Square</th>
<th>F Value</th>
<th>p&lt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>100</td>
<td>1044.2376</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>3</td>
<td>70.7160</td>
<td>23.5720</td>
<td>2.58</td>
<td>0.056 9x</td>
</tr>
<tr>
<td>Prtest</td>
<td>1</td>
<td>135.0381</td>
<td>135.0381</td>
<td>14.79</td>
<td>0.0002 *</td>
</tr>
<tr>
<td>Error</td>
<td>96</td>
<td>876.2510</td>
<td>9.1276</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R=0.1608

*significant p<.05
Table 8
MANOVA of Test 2 By Treatment Group

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sums &amp; Partial Sums of Squares</th>
<th>Mean Squares</th>
<th>F Value</th>
<th>p&lt;(\alpha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>100</td>
<td>1138.5347</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>3</td>
<td>80.7186</td>
<td>26.9062</td>
<td>2.63</td>
<td>0.053 (9%)</td>
</tr>
<tr>
<td>Pretest</td>
<td>1</td>
<td>73.0206</td>
<td>73.0206</td>
<td>7.13</td>
<td>0.008 (9%)</td>
</tr>
<tr>
<td>Error</td>
<td>96</td>
<td>983.8044</td>
<td>10.2480</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R = 0.1359
* significant p<.05
### Table 9
MANOVA of Test 3 by Treatment Groups

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sums &amp; Partial Sums of Square</th>
<th>Mean Square</th>
<th>F Value</th>
<th>P&lt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>100</td>
<td>1153.1681</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>3</td>
<td>1.5697</td>
<td>.5232</td>
<td>0.0500*</td>
<td>.9810</td>
</tr>
<tr>
<td>Pretest</td>
<td>1</td>
<td>66.0765</td>
<td>66.0765</td>
<td>5.95</td>
<td>.0165*</td>
</tr>
<tr>
<td>Error</td>
<td>96</td>
<td>1066.0035</td>
<td>11.1042</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ R = .0756 \]
\[ *\text{significant } p < .05 \]

A follow up analysis of Test 1 using Fisher's LSD is reported in Table 10. Significant differences between the Control and both Groups 2 (p<.0313) and Group 3 (p<.0141) were found. However the significant differences are in favor of the Control, indicating that the control group scored significantly higher than the treatment groups. This point is discussed further under Hypothesis 5.
<table>
<thead>
<tr>
<th>GROUP</th>
<th>LSMEAN</th>
<th>STD ERR</th>
<th>P VALUE BY GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSMEAN</td>
<td>ONE</td>
<td>TWO</td>
</tr>
<tr>
<td>ONE (C)</td>
<td>14.0517</td>
<td>0.6476</td>
<td>.0313*</td>
</tr>
<tr>
<td>TWO</td>
<td>12.1603</td>
<td>0.5819</td>
<td>.6163</td>
</tr>
<tr>
<td>THREE</td>
<td>11.7306</td>
<td>0.6209</td>
<td></td>
</tr>
<tr>
<td>FOUR</td>
<td>13.0465</td>
<td>0.6084</td>
<td></td>
</tr>
</tbody>
</table>

*significant p<.05

The post hoc Fisher's LSD analysis of Test 2 reported in Table 11, indicate that significant group effects were due only to differences between Groups 2 and 3, and Groups 4 and 3. No significant differences occurred in comparison with the Control.
### Table 11
Least Square Means of Groups
Probabilities of Significance in Comparison of
Group by Group For Test 2.

<table>
<thead>
<tr>
<th>Group</th>
<th>LSMEAN</th>
<th>STD ERR</th>
<th>p VALUE</th>
<th>by GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSMEAN</td>
<td>ONE</td>
<td>TWO</td>
<td>THREE</td>
</tr>
<tr>
<td>ONE(C)</td>
<td>12.2672</td>
<td>.6862</td>
<td>.2696</td>
<td>.2970</td>
</tr>
<tr>
<td>TWO</td>
<td>13.2856</td>
<td>.6165</td>
<td>.0259*</td>
<td>.8293</td>
</tr>
<tr>
<td>THREE</td>
<td>11.2360</td>
<td>.6579</td>
<td></td>
<td>.0153*</td>
</tr>
<tr>
<td>FOUR</td>
<td>13.4789</td>
<td>.6447</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*significant p<.05

Although no significant differences appeared between the Control and Test 3 or 4, it is interesting to look at the plotted comparisons of post-test mental rotation scores from Test 1 to test 4, as illustrated in Figure 3. The control group's scores were rather erratic, beginning at its highest point, dipping, and finishing with a lower group mean than at Test 1. Treatment groups 2 and 4, however, experienced a fairly steady improvement from Test 1 to Test 3, with a slight drop at the end. Group 3's scores will be discussed under Hypothesis 6.
Post-test Scores Plotted By Treatment Group

--- Group 1 (CTRL)
...
---- Group 3
___ Group 4

Post-test Scores Plotted By Treatment Group

Figure 3
The graph further seems to indicate some general learning effect from repeated experiences with the mental rotations test. Scores by Test 3 are grouped more closely than in Test 1 and 2.

However, based on the statistical analysis, the study has failed to reject the first null hypothesis.

H02: Persons exposed to visual presentations produced by a three dimensional computer graphics animation system will not score significantly higher on the orthographic views test than the control group.

The MANOVA data for orthographic tests scores, reported in Table 12, indicates a significant difference in group scores for the orthographic views test (p<.0068).
Table 12
MANOVA of Orthographic Test by Treatment Groups

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sums of Square</th>
<th>Mean Square</th>
<th>F</th>
<th>p&lt;.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>100</td>
<td>247.3663</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>3</td>
<td>29.2553</td>
<td>9.7518</td>
<td>4.32</td>
<td>.0068*</td>
</tr>
<tr>
<td>Pretest</td>
<td>1</td>
<td>0.2713</td>
<td>0.2713</td>
<td>0.12</td>
<td>.7296</td>
</tr>
<tr>
<td>Error</td>
<td>96</td>
<td>216.7687</td>
<td>2.2580</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R = 0.1237
* significant p<.05

The post hoc Fisher's LSD indicated significant differences between the Control and Group 3 (p<.0562), and the Control and Group 4 (p<.0006). These differences are in favor of the treatment groups as reported in Table 13. This evidence indicates that the film treatments did have a significant effect on subject's orthographic test scores and therefore, Null Hypothesis 2 can be rejected.
Table 13
Least Square Means of Groups
Probabilities of Significance In Comparison of Group By Group For The Orthographic Views Test.

<table>
<thead>
<tr>
<th>GROUP</th>
<th>LSMEANS</th>
<th>STD ERR</th>
<th>p VALUE by Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LSMEANS</td>
<td>ONE</td>
<td>TWO</td>
</tr>
<tr>
<td>ONE(C) 2.1326</td>
<td>0.3221</td>
<td>.1393</td>
<td>.0562*</td>
</tr>
<tr>
<td>TWO   2.7739</td>
<td>0.2894</td>
<td></td>
<td>.5567</td>
</tr>
<tr>
<td>THREE 3.0246</td>
<td>0.3088</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOUR  3.7323</td>
<td>0.3026</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* significant p < .05
H03: Persons exposed to the following order of visual sequences will not score significantly higher on the Vandenberg/Kuse Mental Rotations Test than those viewing other orders: color/3D, color/2D, wire/3D, wire/2D.

The order of sequences indicated in Hypothesis 3 was that experienced by Treatment Group 4. Since all four sequences would need to be completed before significant effects could be evidenced, only Test 4 of Group 4 was examined. As indicated in Table 14, no significant effects are attributed to group differences in Test 4. Therefore rejection of Null Hypothesis 3 is not possible.
<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sums &amp; Partial Sums of Square</th>
<th>Mean Square</th>
<th>F Value</th>
<th>p&lt;(F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>100</td>
<td>1064.1386</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group</td>
<td>3</td>
<td>33.2053</td>
<td>5.0908</td>
<td>1.6969</td>
<td>.9125</td>
</tr>
<tr>
<td>Pretest</td>
<td>1</td>
<td>84.9186</td>
<td>84.9186</td>
<td>8.62</td>
<td>.0042*</td>
</tr>
<tr>
<td>Error</td>
<td>96</td>
<td>946.0147</td>
<td>9.8543</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ R = 0.1110\]
\[ * \text{significant } p<.05\]
H04: Persons exposed to the following order of visual sequences will not score significantly higher on the orthographic views test than those viewing other orders: color/3D, color/2D, wire/3D, wire/2D.

Group differences for the orthographic views test, as reported under Hypothesis 3 were found to be significant. The order of sequences indicated in this hypothesis also requires the examination of Treatment Group 4. The post hoc Fisher's LSD analysis is reported in Table 13. This analysis indicated that orthographic scores of Group 4 significantly differed not only from scores of the Control (p<.0006) but also from Treatment Group 2 (p<.0246). However, Group 3 scores, although at not as high a level (p<.0562), were also significantly higher than the Control.

Therefore, although there is some indication that Group 4's sequence; color/3D, color/2D, wire/3D, wire/2D, was more effective than the other treatment sequences on orthographic test scores, some of the significant group difference must also be attributed to Group 3, wire/3D, color/3D, wire/2D, color/2D. Because Group 4's test scores were only significantly higher than Groups 1 and 2, Null Hypothesis 4 can be only partially rejected.
H05: Persons exposed to wire frame only for the initial sequence will not score significantly higher on the Vandenburg/Kuse Mental Rotations Test than those who viewed color only for the initial sequence.

Hypothesis 5 requires only an analysis of Test 1, the test immediately following the initial film sequence. As indicated in the discussion of Hypothesis 1, the MANOVA, as reported in Table 6, indicates significant group differences (p<.0539) related to scores of Test 1.

The post hoc Fisher's LSD analysis further indicated that significant differences existed between the Control and Group 2; and the Control and Group 3 (Table 10). Furthermore, the significance was in favor of the Control.

Persons in Treatment Groups 2 and 3 were exposed to wire frame images only for the first sequence, while persons in Group 4 saw only solid color images. This information would lead one to conclude that exposure to wire frame images produced a significant negative effect on the mental rotations scores. Therefore, Null Hypothesis 5 cannot be rejected.
H06: Persons exposed to both three and two dimensional images in the initial two film sequences will not score significantly higher on the Vandenburg/Kuse Mental Rotations Test than those who viewed three dimensional sequences only for the initial two sequences.

Analysis of Hypothesis 6 requires the examination of Test 2 only, the test immediately following the second film sequence. Results of the MANOVA as reported in Table 6, indicated a significant group effect (p<.0539) for Test 2. Although the post hoc Fisher's LSD analysis indicated no significant differences between any group and the Control (Table 11), there were significant differences between Groups 2 and 3 (p<.0259), and Groups 4 and 3 (p<.0153).

Subjects in Groups 2 and 4 experienced first a three and then a two dimensional sequence, while subjects in Group 3 viewed two, three dimensional sequences only for the initial two treatments.

This evidence would seem to indicate that viewing both three and two dimensional sequences was significantly more effective for increasing mental rotation test scores than viewing three dimensional sequences only. Therefore Null Hypothesis 6 was rejected.
Additional notes

In examination of frequencies of raw scores for each test, it was noted that a high percentage of the groups exhibited bi modal curves on the post test, but not on the pretest. This phenomenon may indicate differing subject amenities to the films as a form of instruction. It was not within the scope of this study to examine this problem.

SUMMARY

General findings indicated that viewing computer generated animated images did have a significant effect on increasing subject's orthographic views test scores, but did not significantly improve their mental rotations test scores.

The order in which the four film sequences were viewed also significantly affected subject's orthographic test scores. The sequence of color/3D, color/2D, wire/3D, wire/2D was most effective. The sequence of wire/3D, color/3D, wire/2D, color/2D indicated some significant effectiveness, while the sequence of wire/3D, wire/2D, color/3D, color/2D showed no significant effect.

In attempting to answer the question of whether there could be a significant effect due to wire frame verses color images, mental rotations test scores after only the first treatment were examined. Results indicated a significant negative effect on mental rotation test scores for those subjects viewing wire frame images initially. Subjects viewing wire frame images actually scored significantly worse on the first mental rotation test than the Control.
Finally, in an attempt to determine if viewing objects changing from three to two dimensions could have a significant effect on subjects' mental rotations scores, test scores were examined after subjects had viewed two film segments. Two treatment groups viewed both three and two dimensional images, while one treatment group viewed three dimensional images only. Although no treatment group mean was significantly greater than the Control, the two treatment groups viewing both three and two dimensional images did score significantly higher than the group viewing only three dimensions.
CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The major purpose of this study was to determine if Home Economics students' spatial skills could be improved by viewing computer generated animation of architectural objects rotating and changing from three to two dimensions. A secondary interest was to determine which visual techniques (such as color verses wire frame, or three dimensions verses two) might be more effective in accomplishing this goal. Changes in scores on the Vandenberg/Kuse Mental Rotations Test, and an orthographic views identification test were used to determine changes in spatial skill.

The study was conducted with 101 Home Economics students enrolled in one of two Home Economics courses at The Ohio State University, Winter Quarter, 1985. Students from the two classes were randomly divided into four treatment groups. Three of the groups were shown four animated sequences in differing order and tested after each with the Vandenberg/Kuse Mental Rotations Test. A final orthographic views identification test was given. The fourth treatment group operated as the Control, taking the tests, but not viewing the films.
The data were analyzed with a multivariate technique, first, to determine group effects. A post hoc Fisher's LSD analysis was used to determine the sources and significance of group differences.

The following null hypotheses were tested:

H01: Persons exposed to visual presentations produced by a three dimensional computer graphics animation system will not score significantly higher on the Vandenburg/Kuse Mental Rotations Test than the control group.

H02: Persons exposed to visual presentations produced by the three dimensional computer graphics animation system will not score significantly higher on the orthographic views test than the control group.

H03: Persons exposed to the following order of visual sequences, color/3D, color/2D, wire/3D, wire/2D, will not score significantly higher on the Vandenburg/Kuse Mental Rotation Test than those viewing other orders.

H04: Persons exposed to the following order of visual sequences, color/3D, color/2D, wire/3D, wire/2D, will not score significantly higher on the orthographic views test than those viewing other orders.

H05: Persons exposed to wire frame images only for the initial film sequence will not score significantly higher on the Vandenburg/kuse Mental Rotations Test than those who viewed color images only for the initial film sequence.
H06: Persons exposed to both three and two dimensional images in the initial two film sequences will not score significantly higher on the Vandenburg/Kuse Mental Rotations Test than those who viewed three dimensional images only for the initial two film sequences.

Discussion

In examining Hypotheses 1 and 2, the analysis of data indicated that subjects who viewed the films scored significantly higher on the orthographic views test \((p<.0068)\), but not on the mental rotations test.

There are several reasons why significant differences might have been attained for the orthographic and not the mental rotation test. First, objects shown on the treatment films more closely simulated the objects on the orthographics views test, making it easier for subjects to directly apply any learning which took place from the films.

Furthermore, research by Olson and Bialystok (1983) indicated that canonical objects, those with easily identified differences in top/bottom, front/back and left/right, are easier to rotate than non canonical objects. The orthographic views identification test objects were mostly of a canonical type, while the mental rotation test objects were not.

Other research by Olson and Bialystok determined that watching films of objects rotating was nearly as effective in teaching mental rotation as actual experiences. This study did not find the viewing of films to significantly affect mental rotation test scores. However,
Olson and Bialystok's research involved using filmed objects similar to the Vandenbarg/Kuse objects and then testing subjects with the Vandenbarg/Kuse Mental Rotations Test. In their case the direct application of information applies as it did in this study for the Orthographic views test.

Therefore, some indication exists that mediated rotations of objects may be effective for similar types of objects, but not be as effective for transfer to all objects. The amount of time that films are viewed could also be a factor. In both this study and that of Olson and Bialystok, film viewing time was relatively short (20 and 12 minutes respectively). Perhaps more viewing over a longer period of time could encourage transfer to other objects.

The order in which subjects viewed the sequences also attributed to significant differences in orthographic but not mental rotation test scores. The most effective series (p<.0006), color/3D, color/2D, wire/3D, wire/2D, was selected by the researcher, previous to data collection, as most likely to succeed because of its logical order. Subjects first saw the object in its most natural, solid color, three dimensional form. The objects then were seen changing to two dimensions. The third sequence offered greater information by showing the object in wire frame, but at the same time losing some of its natural identity. The object made the transition to a flat two dimensional line drawn object in the final sequence.

Therefore, the subjects viewed the transition of the object in logical sequence from three dimensions, solid to two dimensions, wire frame. This logical sequence of learning is in harmony with Gagne's (1977) theories of hierarchichal learning. Subjects may have entered
this study with certain spatial concepts about objects. A conceptually logical order of sequences could allow the subject to change simple spatial concepts into more complex discriminations, concepts and rules.

The sequence wire/3D, color/3D, wire/2D, color/2D indicated some significant effectiveness ($p < .0562$). While this sequence is not as logical as the first, the strong input of two dimensions at the end of the study probably contributed to success on the orthographic views test. This idea will be discussed in detail in following paragraphs.

The third order of wire/3D, wire/2D, color/3D, color/2D showed no significant effect on orthographic scores. It is this researcher's opinion that seeing wire frame images first, without having viewed the objects in their natural form, would be confusing to the subjects. Furthermore, the solid color objects viewed directly before taking the orthographic views test would not be as helpful, since the level of transfer from solid color to line drawn would be larger than from wire frame to line drawn test images.

One could therefore conclude that viewing logical transitions of objects from solid, three dimensions to wire frame, two dimensions would be the most effective strategy to follow for the instruction of orthographic drawing.

The issue of which is most effective, color or wire frame images, has been discussed in the preceding paragraphs for the orthographic views test. However, statistical analysis of the first mental rotations test scores indicated that initially the wire frame images had a negative effect on learning. This finding contradicts findings by Dwyer (1978), which indicated that line drawn illustrations of images are more conducive to learning than more realistic ones.
However, Dwyer's research applied to static two dimensional images. Animation of line drawings in three dimensions are often confusing, especially to the novice.

The final question of interest to this study was whether viewing three dimensional or two dimensional images was most effective for spatial learning. The findings are indicative of mental rotations test scores only. Although no treatment group was significantly higher than the Control, the two treatment groups viewing both three and two dimensional images did score significantly higher than the group viewing only three dimensions on the mental rotation test. There is no evidence as to why the two dimensional information would have any effect on mental rotation tasks of three dimensional objects. Further study in this area is necessary.

RECOMMENDATIONS FOR FURTHER STUDY

Based on the information gained from this study as well as a review of the literature, the following recommendations for further study are made:

1. Investigate further the relationship between mental rotation skills and orthographic drawing skills.

2. Determine the effect of time on mental rotation and orthographic views test by replication of this study using longer film viewing times and/or controlling the number of days between treatments.
3. Investigate the effect of spatial preknowledge of subjects on test scores. Is treatment more effective for those who already have some skills in the area, or for those with very little skill?

4. With the use of computer animation software, develop highly realistic objects and compare their effectiveness with the solid color and wire frame images already developed for this study.

5. Experiment further with the order of film sequences, such as one treatment group viewing only wire frame for four sequences, or only three dimensions.

6. Determine if the angle in which the objects are viewed affects the "understandability" of the image, by developing additional film sequences similar to those in this study with only the view angle changing.

7. Investigate further the debate between the effectiveness of solid color verses wire frame images.

8. Replicate this study with different samples, controlling for age, sex, formal operational level, previous training, math abilities, or cerebral hemisphere dominance.
9. Investigate the internal processing patterns of the brain, identifying differences when viewing the four different visual sequences.

CONCLUSION

Computer graphics animation has potential as a resource for the instruction of spatial skills. This study has indicated that images created and animated through computer systems are useful for learning orthographic drawing.

Because the field of computer graphics is still new and in a developmental stage, the full capabilities and application of the technology are yet to be discovered. However, in its present state, computer graphics can be incorporated into the classroom for spatial skill instruction. Its use could be similar to the design of this research with students viewing either films or video tapes of objects rotating and changing dimension. After viewing films, students could reinforce the learning experience with orthographic views identification practice and/or actual drawing experiences.

Video tapes might also be interfaced with personal computers and an interactive software system such as Super Pilot, offering individualized experiences for students. Such software packages also offer the capability of simultaneously displaying multiple views on the screen at the same time. Instruction might be enhanced further by permitting students to have control over the animation, stopping it when a rotating image reached a previously specified viewpoint.
As indicated previously, additional images could be created and animated by making minor changes to the existing computer animation program. Therefore, other fields of study, such as Engineering Graphics, Textiles and Clothing or Industrial Design could adapt these instructional stimuli for a specific purpose.

The spatial visualization instruction could be taken a step further by using images of actual objects or architectural features within the student's classroom. The student could then conceptualize the scale transition as well as rotation and perspective.

Presently, the hardware to create such animation would be cost prohibitive to many educational institutions. Furthermore, good software is not readily available for image production. Given the technology's fast-paced development, these problems may be remedied in the near future. Therefore, it may be possible for a student to work at a computer and choose from a bank of already prepared images or create his/her own. She could then view animations of that image directly on the computer monitor. Such systems are emerging for personal computers. The gap between the graphics abilities of large computer systems and the small personal computer is closing quickly. The trend towards high quality, user-friendly graphics systems is readily apparent.

The results of this study have raised some provocative questions for the entire area of graphics instruction. In particular, images used in this study when seen initially in wire frame seemed to be confusing to subjects. Quite often initial drawing instruction involved showing images as line drawings (wireframe). Perhaps it would be more useful for the student to see first the object in solid color
or shaded form, and then make the transition to wireframe. The order of sequence; color/3 dimensions, color/2 dimensions, wire/3 dimensions, wire/2 dimensions, might be the optimal sequence for orthographic instruction.

One final concern should be addressed. Introduction of new technology into the classroom is often difficult. It not only interjects a new instrument into the learning environment, but may also require new instructional methodology. The instructor, students, or both may not be receptive to such innovations. If computer graphics is to become an effective teaching tool, it must be offered in a package that is easy to use, and both cost and time efficient.

It is therefore necessary to investigate both, the researchable questions in the area of orthographic drawing skills instruction, and the challenge of finding ways to apply such knowledge in the varied courses, students and teaching styles.
APPENDIX A

MENTAL ROTATIONS TEST, ORTHOGRAPHICS TEST AND

PERSONAL INTERVIEW SHEET
M.R.T. Test

pretest

This is a test of your ability to look at a drawing of a given object and find the same object within a set of dissimilar objects. The only difference between the original object and the chosen object will be that they are presented at different angles. An illustration of this principle is given below, where the same single object is given in five different positions. Look at each of them to satisfy yourself that they are only presented at different angles from one another.

Below are two drawings of new objects. They cannot be made to match the above five drawings. Please note that you may not turn over the objects. Satisfy yourself that they are different from the above.

Now let's do some sample problems. For each problem there is a primary object on the far left. You are to determine which two of four objects to the right are the same object given on the far left. In each problem always two of the four drawings are the same object as the one on the left. You are to put Xs in the boxes below the correct ones, and leave the incorrect ones blank. The first sample problem is done for you.

Go to the next page

Adapted by S.G. Vandenberg, University of Colorado, July 15, 1971
Revised instructions by H. Crawford, U. of Wyoming, September, 1979
Do the rest of the sample problems yourself. Which two drawings of the four on the right show the same object as the one on the left? There are always two and only two correct answers for each problem. Put an X under the two correct drawings.

Answers: (1) first and second drawings are correct
(2) first and third drawings are correct
(3) second and third drawings are correct

This test has two parts. You will have 3 minutes for each of the two parts. Each part has two pages. When you have finished Part 1, STOP. Please do not go one to Part 2 until you are asked to do so. Remember: There are always two and only two correct answers for each item.

Work as quickly as you can without sacrificing accuracy. Your score on this test will reflect both the correct and incorrect responses. Therefore, it will not be to your advantage to guess unless you have some idea which choice is correct.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO
TEST 2

11.

12.

13.

14.

15.

GO TO THE NEXT PAGE
ORTHOGRAPHIC VIEWS TEST

In each of the six problems select the group of three orthographic views which correctly describes the object shown pictorially (upper left).
All views in a group must be correct. Indicate your choice with an "X" over the selected group. If no group is correct, mark an "X" over the pictoral.
PERSONAL INTERVIEW SHEET

Name ________________________________
Cols. Address ____________________________
Perm. Address ____________________________
Cols. Phone ___________ Perm. Phone ___________
Sex (M,F) ___ Dominant hand (Rgt/Left) ______
Major _______________ Intended Occupation ______
Mother's Occupation _______________________
Father's Occupation _______________________

Previous Drawing Experience
Type (free hand, technical) ______
Where/When (high school, college, private lessons, job) ______

Clothing Construction Ability (none, some, extensive) ____________

Average Math Grades (A,B,C,D)
High School _____________ College ______

Attitude Toward Math (like, dislike, neutral) ______
Attitude Toward Drawing (like, dislike, neutral) ______

Types of House You Have Lived In: Beginning with the first house, list age, location and type to date.

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Name the three objects seen in the test films.
1. ______
2. ______
3. ______
APPENDIX B

RAW SCORES OF SUBJECTS BY TREATMENT GROUP
## GROUP 1 CONTROL

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APPENDIX C

ORTHOGRAHIC VIEWS LECTURE AND TRANSPARANCIES
Orthographic Views Lecture

1. Persons involved in descriptions of objects find the need to use graphics to communicate information about those objects to other persons. This may include the object's size, and/or shape.

2. In the area of Home Economics, these objects may be an interior of a room, a piece of furniture, articles of clothing, or a sewing pattern.

3. In such fields as clothing construction, housing, interior or fashion design, graphics becomes the primary method of communication. Verbal - language becomes secondary.

   For most people, this is contrary to their normal method of communication and therefore they find it difficult.

4. Orthographic projection is one method of communicating shape and size information graphically.

   It is defined as: A set of two or more separate views of an object taken from different directions. Each view shows the shape of the object for a particular view direction and all views together describe the object completely.

5. (Fig. 1) (The following parts are identified)

   Object

   Picture Plane (your paper)

   Station Point
Rays of Projection (closer - more angle/ farther away less angle)

6. (Fig. 2) Orthographic: person stands at infinity
   Rays become perpendicular to the picture plane
   Rays become parallel to each other

7. (Fig 3 & 4): Frontal plane
   Horizontal plane (top)

8. (Fig. 6) Glass box: 3 Primary planes
   Front
   Top
   Side (profile)

9. In order to make drawings of each plane a person must either be able to rotate the object physically or mentally.

10. For most of us mental rotation or spatial skill training is limited.

11. The purpose of this experience is to give you some training in spatial skills. The training will involve viewing films of objects rotating, as well as some test-like experiences.

12. The project will include today's class time as well as a part of another class time.
FIG. 1. Perspective projection. The rays of projection converge at a station point from which the object is observed. Rays intersect a picture plane and produce a projection of the object.
Fig. 2. Orthographic projection. The station point is at infinity, making the rays parallel to each other. The rays are perpendicular to the picture plane.
FIG. 3. The frontal plane of projection. This produces the front view of the object.

FIG. 4. The frontal and horizontal planes of projection. Projection on the horizontal plane produces the top view of the object. Frontal and horizontal planes are perpendicular to each other.
FIG. 6. The three planes of projection: frontal, horizontal, and profile. Each is perpendicular to the other two.
References


