AN EXPLORATORY STUDY TO DETERMINE GUIDELINES FOR THE SELECTION AND PRODUCTION OF VISUALS FOR USE ON CONTROLLED - SCAN TELEVISION IN A CLASSROOM SETTING

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H. JAMES SPOONER

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This is to certify that the

thesis entitled

AN EXPLORATORY STUDY TO DETERMINE GUIDELINES FOR THE SELECTION AND PRODUCTION OF VISUALS FOR USE ON CONTROLLED-SCAN TELEVISION IN A CLASSROOM SETTING

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ABSTRACT

AN EXPLORATORY STUDY TO DETERMINE GUIDELINES FOR THE SELECTION AND PRODUCTION OF VISUALS FOR USE ON CONTROLLED-SCAN TELEVISION IN A CLASSROOM SETTING

By

H. James Spooner

Purpose of the Study

The purpose of this exploratory study was to develop guidelines for the selection and production of visualized instructional materials for use on controlled-scan television in a classroom setting. CSTV is a new video broadcast medium offering economies of cost and bandwidth but is limited to displaying still pictures at a relatively slow frame rate (seven seconds for this study). It was theorized that display limitations could be compensated for graphically.

Procedures

Development of guidelines was based on data derived from an experimental determination of legibility standards for the new medium. The relationships to legibility of

three independent variables were examined: (1) visual angle (a function of symbol size and viewer distance), (2) brightness contrast (characters to background), and (3) viewing angle. Legibility was operationalized as the scores of 72 upper elementary school students viewing and accurately identifying a total of 30 sets of characters (alphanumerics, inverted alphanumerics, and geometric forms) displayed via CSTV on a 23-inch TV set. Each subject, screened for visual acuity, was randomly assigned to one of 12 treatment groups to view ten sets of characters at each of three contrast conditions (high, medium, low) within one of four sizes (1/4, 3/8, 1/2 or 5/8-inch height at the screen). Within groups, subjects were randomly assigned to viewing positions six and one quarter screen widths distance from the receiver at angles of 9 degrees, 27 degrees, or 45 degrees to the right or left of a center line. Subjects were exposed to each set (5, 4, or 3-characters per set) for ten seconds with instructions to copy the characters displayed; there was a five-second lapse between sets. Total time per treatment was seven and one half minutes. The sets of visuals were transmitted on-air via a sub-carrier channel of an FM radio station for each of the 12 treatments.

The statistical design of the study was a 36-cell matrix created by the 12 treatment groups (four sizes of display symbols by three viewing angles) with three sets of repeated measures (the three contrast conditions). Four hypotheses were postulated to test the main effects and their interactions at the .05 alpha level. Univariate analysis of variance with repeated measures was used to test the hypotheses. The Scheffé method of multiple comparisons was applied *post hoc* to significant sources of variation. The reliability of the test instrument was estimated and a descriptive item comparison of the three types of characters was undertaken.

Conclusions

Analysis of variance indicated that two of the three main variables (1. visual angle, i.e. size, and 2. brightness contrast) and one two-way interaction (size by contrast) had significant effects on legibility.

Conclusion 1. To be legible to upper elementary school students with normal vision, characters displayed on CSTV should subtend a vertical visual angle of at least 17 minutes of arc (5/8-inch height at the screen when viewed from a distance of 10.5 feet).

Conclusion 2. A high or medium contrast ratio (representing no fewer than six shade separations on the TV ten-step gray scale) of character-to-background will ensure legibility for displays via CSTV. Low contrast conditions with as few as three shades of separation should be avoided where discrimination is required.

Conclusion 3. Upper elementary school students with normal vision should experience equal legibility of displays via CSTV when viewing occurs within a 90 degree cone emanating from the TV receiver.

Conclusion 4. To be legible to upper elementary school students with normal vision, low contrast conditions on CSTV displays should be avoided regardless of sizes of characters.

The descriptive comparison of types of characters showed differences between regular alphanumerics and the other two types. Regular alphanumerics were more readily identified suggesting that previous learning by subjects influenced their ease of identifying characters. It was concluded that characters which are unfamiliar to viewers should be treated differently from those which are familiar by making the unfamiliar characters larger.

Specific guidelines related to visual angle (size of characters viewed from various distances), brightness contrast (characters to background relationship), and viewing angle were developed from the conclusions.

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by

H. James Spooner

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DEDICATION

To those persons whose personal interest in me has been sincerely appreciated by me:

to my mother and late father whose priority was that their sons receive a good education;

to my in-laws, Oscar and Myrtle Johnson, whose support has always been there;

and especially to my wife, Bev, and three children, Barbi, Cheri, and Rob, who willingly shared in putting husband and father through university.

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CHAPTER I

THE PROBLEM

Introduction

Whenever a new medium appears on the communications scene, its instructional potential becomes the interest of education. Such a new medium is controlled-scan television (CSTV), a broadcast technology capable of transmitting a still picture and audio signal in the narrow bandwidth range. Its potential suggests sufficient promise to educators to encourage research into the use of CSTV where still visualization is essential to instruction. The Elementary and Secondary Education Act, Title III, has authorized research projects at Flint, Michigan, and South Bend, Indiana, to test the feasibility of using CSTV in public classroom instruction.

Controlled-Scan Television

Southworth defines controlled-scan television as "a video system in which one second or more is required for the transmission of a single frame of information."[1] The

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[1]Glen R. Southworth, "Educational Uses of Slow-Scan Television," Educational/Instructional Broadcasting, III, No. 11 (1970), 35.

image produced is comparable to the projection of a 35 mm slide in that both are incapable of motion. Unlike the instantaneous display of a slide, however, a display on CSTV requires time as the image literally builds vertically or "wipes" on the blank television screen from left to right. The time lapse of the wipe may vary, ranging from four seconds for a low resolution picture to six minutes for a high resolution image.[2] The frame rate set by Colorado Video, Incorporated, and Gates Radio Company, Quincy, Illinois, manufacturers of equipment used at Flint and South Bend, is seven seconds. When the presentation mode is "automatic," a seven-second wipe occurs followed by a blank screen. Then another image builds. On "manual" operation the image is held indefinitely by a magnetic memory disc until triggered to change.

A simple controlled-scan system uses an industrial grade television camera, a video converter (encoder) which compresses the video spectrum to audio range, two SCA (Subsidiary Communications Authority) generators to transmit the audio and video messages, two SCA receivers at the destination of the messages, a video converter (decoder) to restore the 525-line viewing rate, and standard television receiving sets. CSTV can be transmitted on-air via signals

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[2]Southworth, op. cit., p. 37.

reduced to the audio range (e.g., on ham radio frequency or sub-carrier channels of AM or FM radio transmitters) or on-line via voice-grade telephone lines.[3] While controlled-scan television possesses the capability of color, to date this potential has not been exploited.

The major advantages of CSTV derive from the narrow bandwidth of the video signal. Bandwidth reduction represents a sizeable economy of broadcast spectrum space and promises savings in costs. Unlike broadcast television which requires thirty complete images per second (frame rate) over a spectrum space of four megaHertz, CSTV with its slower frame rate can operate at 1/1000th of the standard bandwidth. The economy of spectrum space is obvious; the savings in cost are realized through reduced capital expenditures, and lower transmission and maintenance costs. For example, reduced capital costs may be realized by using existing broadcast transmitters or existing telephone networks, although the video converters required to condense and expand the signal represent a significant capital consideration (Colorado Video Converter 220-A lists at $5,000.00).

Part of the Flint Title III project is an analysis of on-air costs of production and transmission using the

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[3] Teaching with Controlled-Scan Television, Adjusted Pilot Project Proposal of Grant 0601, Michigan Department of Education, ESEA Title III, Lansing, Michigan, 1971, p. 14.

sub-carriers of WFBE-FM. Southworth gives as an example of on-line economy that standard "voice-grade" telephone circuits may cost as low as $3.00 per airline mile per month.[4] Elmore states that on-air transmission is faster and less costly than on-line.[5]

In addition to spectrum and cost savings, Southworth cites these advantages of CSTV:

1. Utilization of existing communications facilities such as telephone lines, FM subcarrier, private microwave, low-power radio transmitters.
2. Video recording on one-quarter inch tape.
3. Inherent image storage capability.
4. Convenient computer interfacing.
5. Highly flexible input-output format as compared to facsimile or computer terminals.[6]

In spite of the cited advantages, however, Southworth advises educational users of CSTV to be aware of "the trade-off factors relating to resolution, bandwidth and the amount of time required to transmit a single image."[7]

Need for the Study

When compared to other television forms the image on controlled-scan appears inferior to that of standard

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[4] Southworth, op. cit., p. 35.

[5] C. Elmore, "Compressing TV on an FM SCA Channel," Broadcast Engineering (November, 1971), 35.

[6] Southworth, op. cit., p. 37.

[7] Loc. cit.

instructional quality TV, either closed-circuit or broadcast. Technically, a general signal degradation occurs on CSTV affecting resolution, contrast and signal-to-noise ratio. When viewing a common image on both CSTV and standard TV, the viewer of controlled-scan sees a generally coarser, but recognizable, representation than on standard television. The image quality (legibility) of CSTV and its effects on learning should be basic concerns of education if controlled-scan is to become part of instructional technology.

If CSTV is to be used in a classroom setting, it becomes apparent that guidelines for its use should be determined. For example, a major concern to teachers will be "software" or the materials required to present visual content. Only as users become aware of the design requirements of pictures to be transmitted on CSTV can they have confidence in the instructional potential of this new medium. Kessler and Wilhelm advise that design problems "can be best prevented by carefully defining the required performance of the graphics system before the equipment is chosen and installed."[8] To this end, Kasten recommends a basic legibility study for alternate television forms

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[8]Wm. Kessler and Michael Wilhelm, "Narrow Bandwidth Telecommunications," Proceedings of the Conference on Interlibrary Communications and Information Network (Chicago: American Library Association, 1970), p. 37.

intended for instructional use.[9] To date no formal study of controlled-scan television for use in public classrooms has been completed.

If CSTV is to become a recognized broadcast technique, then its capabilities should be determined and its transmission requirements should be accommodated. In planning for the future both the Federal Communications Commission and the proposed Telecommunications Network of the State of Michigan wish to study the uses of CSTV, including its educational role. Exploratory studies of the instructional applications of CSTV will aid national, state, local, and system agencies in planning to meet communication needs.

In this age of demands for accountability and cost-effectiveness in education and concern about priorities on the telecommunications scene, CSTV represents an economical alternative to existing means of broadcasting visual content. Without formal studies of its effectiveness, CSTV will remain an unproved alternative.

Purpose

The purpose of this study is to determine guidelines for the selection and production of visualized instructional materials for use on controlled-scan

[9] Duane Kasten, "A Study of Five Factors Influencing the Legibility of Televised Characters," (Dissertation, Purdue University, 1960), p. 31.

television. Determination of the guidelines will be based on an experimental exploration of the legibility of controlled-scan images in an instructional setting.

General Statement of Hypotheses

The general hypothesis of this study is that there is a relationship between (1) visual angle, (2) brightness contrast, and (3) viewing angle to legibility of a display on controlled-scan television as viewed by upper elementary school students in a classroom setting. Significant questions emerging from this hypothesis are stated as follows:

1. What is the relationship between visual angle (a function of symbol size and viewer distance) and legibility of a display on CSTV as viewed by upper elementary school students in a classroom setting?

2. What is the relationship between brightness contrast (symbol to background) and legibility of a display on CSTV as viewed by upper elementary school students in a classroom setting?

3. What is the relationship between viewing angle and legibility of a display on CSTV as viewed by upper elementary school students in a classroom setting?

4. What are the interaction effects between/among visual angle, brightness contrast, and viewing angle in their relationship to legibility of CSTV?

Based on answers provided by experimental testing of these questions, guidelines were developed for the selection and production of visual materials for use on controlled-scan television in an instructional setting.

Definition of Terms

Understanding of the following terms is pertinent to this study:

1. Accuracy of identification. The number of characters correctly identified by copying them from the television screen onto paper.

2. Ambient illumination. The light incident upon the display and surrounding areas measured in foot-candles.

3. Band. A portion of the frequencies in the electro-magnetic spectrum allocated by the Federal Communications Commission for specific applications to AM radio, FM radio, VHF television, UHF television, Instructional Television Fixed Service, and Ham Radio operators.

4. Brightness contrast. The measure of difference between the brightness of a symbol or character in relation to its background. The relationship is expressed as a ratio.

5. Characters. Individual symbols or figures such as letters and numbers displayed as stimuli on CSTV.

6. Controlled-Scan television (CSTV). A video-audio system in which one second or more is required for the transmission of a single video frame of information.

7. Frame. A single picture as displayed on a viewing screen by CSTV.

8. Frame rate. The time in seconds required to develop a single televised frame. The frame rate of CSTV for this study is seven seconds.

9. Gray scale. A graduated measure of values or shades of gray in ten steps from white to black. The gray scale reference for this study was the Electronic Industry Association (EIA) Logarithmic Chart.

10. Legibility. The property which pictures and symbols possess when they are capable of being read. Legibility is operationalized as the accuracy of identification of characters displayed on a viewing screen by CSTV as viewed by subjects.

11. Optimal viewing distance. That distance 6¼ times the image width (TV screen). At this distance the eye moves in a well-dispersed pattern of fixation (subtends a visual angle of nine degrees) taking in the whole display rather than parts of it.

12. Resolution. The detail which can be distinguished on the television screen.

13. Signal-to-noise ratio. The proportion between the level of the video signal and the level of the noise and/or interference accompanying it.

14. Visual angle. The minutes of arc that a target image subtends on the retina of the eye. It is a function

of viewer distance from the image and the vertical size of the image at the television screen surface. Because viewer distance for this study remains constant, the term size (height of symbols) will be used interchangeably with visual angle.

15. Viewing angle. The angle in degrees that the viewer of a television screen is off-axis to a line drawn perpendicular to the screen surface.

Theory Underlying the Study

If a student is to learn from visual materials he must be able to see them; that is, physical clarity of visuals is fundamental to a student learning from them. Seibert, Kasten, and Potter support this premise when they state:

> It was obvious that visual information could not be communicated to students except when conditions permitted their accurate perception of the transmitted information. A visual message that is 'below the threshold' for the individual student will not have its intended effect.[10]

Most studies on visualized instruction take for granted the necessity of visual clarity or legibility. Often legibility becomes a consideration only when results are inconclusive and an explanation is sought. For example, in an experimental study on "The Effectiveness of Visual Presentations

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[10] Warren F. Seibert, Duane F. Kasten, and James R. Potter, " A Study of Factors Influencing the Legibility of Televised Characters," Journal of the Society of Motion Picture and Television Engineers, LXVIII (July, 1959) 467.

of Different Sizes," Dwyer refers to the blurriness of visuals and the difficulty of students in perceiving them as reasons for the ineffectiveness of large-size illustrations to instruct.[11]

A second theoretical consideration is that there is a threshold of identification, a measurable point at which recognition and discrimination among forms becomes possible.[12] That threshold can be determined by controlled testing of subjects with normal or corrected vision. Determination of the threshold is a function of the form or image, the viewer, viewing conditions, and, in the case of instructional media, the medium by which the image is projected or transmitted.

Measurement of the visual threshold is expressed by the visual angle of an image subtended at the eye, which for television is a function of height (vertical size) of the image (in inches) at the screen surface and viewer distance from the screen (in feet). The critical angle may be determined by displaying different sizes of printed characters to viewers seated an optimal distance from and

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[11]Francis M. Dwyer, A Guide for Improving Visualized Instruction (State College, Pennsylvania, Learning Services, 1972), p. 39.

[12]Colin Pitlado, A. J. Lincoln, and Lloyd Kaufman, (Sperry Rand) "Evaluation of Narrow BW TV Displays," from Technical Session Proceedings, 7th National Symposium on Information Display (Boston, Mass., October, 1966), p. 150.

at varied angles to the screen. Accuracy of identification by the viewers determines the degree of legibility of the characters. The higher the accuracy, the greater the legibility. Once the critical angle of subtension is determined, it can be translated into both vertical size of characters at the screen and viewer distance. This is important for instruction in a classroom setting where viewer distances vary and size of characters becomes a critical consideration for legibility.

A further consideration is the nature of the presentation medium *per se*. There is increasing awareness by instructional technologists that each individual medium has unique characteristics and limitations which influence its role in instruction. This premise of often ignored by researchers who attempt to compare methods of presentation. Dwyer suggests:

> Many studies attempt to compare the effectiveness of the various media in presenting the same information, but do not give adequate consideration to the inherent capabilities and limitations [of the different types of media]. In some instances, it would seem inappropriate to compare the effectiveness of a motion picture and a series of slides abstracted from the film in presenting the same information.[13]

As the distinct properties of each medium are identified and their capabilities determined, it becomes beneficial to instruction to interpret their influences on software.

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[13] Dwyer, *op. cit.*, pp. 79-80.

Materials designed for one medium may be inappropriate for use on another because of inherent differences in the natures of the media. For example, materials designed for a highly detailed film-based projection system may be inappropriate for use on a television system which is less capable of rendering detail.[14] Neal expresses this concern when he says:

> If printing or other fine detail appears in a television movie, a teacher might assume that the producer made it big enough to see. In fact, because of basic differences between television and film quality, as well as the discrepancy between the intended and actual image size, some movie frames may be quite unintelligible when seen on TV.[15]

Unique characteristics of CSTV are: (1) a still image, (2) the vertical scanning process or "wiping" by which an image is constructed, (3) the noticeable time lapse required to establish a complete image (frame rate), and (4) the capability of indefinitely holding or storing an image. Limitations of CSTV include the inability to convey motion and achieve image resolution equivalent to standard TV within an instantaneous frame rate.

The limitation of motion is an inherent feature of the medium for which there is no compensation, although

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[14] G. F. McVey, "Legibility and TV Display," Educational Television, II, No. 11 (1970) 18.

[15] Alan S. Neal, "Legibility Requirements for Educational Television," Information Display Journal, V, No. K (1967) 40.

still pictures often possess a dynamic property which suggests activity.[16] While motion is an absolute limitation on CSTV, it is theorized that limited resolution may be compensated for by graphic design, especially where printed letters, numbers or symbols are involved.

Limitations of the Study

Facets of this study which limit the interpretation of results are as follows:

1. This study is limited to the subject sample of upper elementary school students drawn from a single school within the Flint school system. Only students with normal visual acuity were used as subjects.

2. This study is limited to the controlled-scan television system used for this experiment. That is, it is restricted to black-and-white television; it is limited to a television signal broadcast live, on-air (not recorded); and it is further limited to a frame rate of seven seconds.

3. This study is limited to identification of stimuli displayed in the center of the television receiving set as opposed to display over the whole screen.

4. This study is limited to digital signs (e.g., alphanumeric characters) as opposed to iconic signs (representative pictures) to test legibility.

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[16] Godwin C. Chu and Wilbur Schramm, Learning from Television: What the Research Says (National Association of Educational Broadcasters, 1967) p. 95.

5. This study is limited to identification of individual characters; no meaningful combinations of characters, such as words, were used as stimuli.

Overview

A frame of reference for the study is developed in Chapter I. Included are an introduction, need for and purpose of the study, general statement of hypotheses, definition of terms, and the theory underlying the study.

Literature pertinent to the study is reviewed in Chapter II. In particular, literature on visualized instruction and television legibility is discussed.

In Chapter III the design of the study is presented including the sample, stimulus material, equipment and facilities, description of experimental conditions, instrumentation, procedure, research hypotheses, experimental design and analysis.

Analysis of the data is examined in Chapter IV.

In Chapter V, a summary of the study, conclusions, and implications for further research are presented.

CHAPTER II

REVIEW OF THE LITERATURE

There is a large body of research on the use of television in education as evidenced by Chu and Schramm's Learning from Television: What the Research Says (Washington, D. C.: Nat. Assoc. of Ed. Broadcasters, 1967), Reid and McLennan's Research in Instructional Television and Film (Washington, D. C.: U. S. Printing Office, 1967), and Kumata's An Inventory of Instructional Television Research (Ann Arbor, Michigan: Ed. TV and Radio Center, 1956). The current state of research as reviewed by William Allen indicates that instructional television (ITV) has passed the period of proving itself as a substitute for conventional teaching. Allen states:

> The predominant finding from the hundreds of evaluation studies in instructional television is its overall equal effectiveness when compared with face-to-face instruction. That students learn from televized teaching cannot be doubted, but the conditions under which such learning takes place and the specific characteristics of televised presentations that bring this about are yet to be determined, and most research ignored such questions.[1]

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[1]William Allen, "Instructional Media Research: Past, Present, and Future," AVCR, XIX, No. 1 (1971), 10.

The major conclusion that Chu and Schramm draw from their survey agrees with Allen, that television can teach: "This evidence now comes from many countries from all studies of all age levels from preschool to adults and from a great variety of subject matter and learning objectives." (p.98)

Given that television can teach, the direction of research in ITV is now shifting toward other concerns.

Literature pertinent to this study is reviewed in this chapter. Two areas of interest suggest the organization of the chapter: (1) visualized instruction, and (2) legibility of instructional television. Visualized instruction is a broad area lending itself to many approaches; much of its literature is in the formative stage as researchers attempt to standardize visual terminology, conceptualize visual functions, and refine visual theory. By contrast, the area of legibility of instructional television is narrow, depending on precise experimental measurements for results. Literature on legibility for group instruction is limited, but selected studies from education, perceptual psychology and human factors engineering contribute to the development of standards for classroom use. Both areas of study, visualized instruction and legibility, share a common concern for improving instruction through more effective visual materials.

Visualized Instruction

Whether they are sketch drawings on chalkboards, illustrations in textbooks, or projected slides and movies, visuals have traditionally played a role in formal instruction. Users of visuals contend that they provide an interest or motivational factor to learning and help clarify the meaning of objects and concepts. Maps, charts, and graphs with their capacity to compress information are well known visual sources used by experienced teachers. Dwyer summarizes the attitude of educators toward the use of visuals as follows:

> Visualization of content material is said to be able to:
>
> 1. Facilitate the accuracy and standardization of the message being communicated;
> 2. Bring into the classroom inaccessible processes, events, situations, materials, and phase changes in either space or time;
> 3. Illustrate, clarify, and reinforce oral and printed communication, quantitative relationships, specific details, abstract concepts, and spatial relationships;
> 4. Provide concreteness (realistic detail) in the learning situation;
> 5. Increase student interest, curiosity, and concentration;
> 6. Present to the learner the opportunity to perceive an object, process, or situation from a variety of vantage points;
> 7. Provide important instructional feedback.[2]

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[2] Dwyer, *op. cit.*, p. 1.

To date there has been a general attitude that one picture is as good as another for instructional purposes, and that the same picture presented on any medium will have the same learning impact on any audience. This attitude is now being questioned as researchers investigate the effects of pictorial stimuli on learners.

Mounting interest in the use of visuals in instruction is due in part to the development of newer visual media, particularly television. Impetus for study also comes from the realization that "the present methods of selecting and using visual materials for instructional purposes are grossly ineffective and wasteful and that, in many cases, for specific educational objectives visualization of content material is no more effective than the same instruction without visualization."[3] The design and production of visuals has been at the subjective whim of the artist. Little effort has been expended to isolate, classify, and measure essential stimuli characteristics of visuals in their relationship to learning.

The types of questions now being asked by researchers are:

> Are certain pictorial styles more effective than others for achieving specific learning objectives? For optimum learning, how many pictorial elements and which specific ones should a display contain? How do individuals respond to different types of

[3]Dwyer, p.v.

> illustration styles? Which do they prefer most or least? What kinds of paradigms are illustrative of visual information procedures and visual perception? How do ethnic groups react to various types of pictures?[4]

As indicated by the above list, the study of visualized instruction lends itself to many approaches. Those perspectives most contributory to this study are the ones which influence the design and selection of still pictures for instructional purposes. They are: (1) the definition of pictures, (2) critical variables in visual instruction, and (3) the application of results to instructional television.

The Definition of Pictures

What is a picture? A recent theorist to study this problem and attempt a definition is James Knowlton[5] who builds on earlier studies by Morris[6] and Gibson[7]. Essentially he defines pictures as signs (including symbols) that represent objects or concepts; signs are produced with the intent of communicating visually. Meaning from the signs

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[4]Pascal Trohanis, "ITV Pictorialism: A Bibliography," Educational Broadcasting, IV, No. 10 (1971) 9.

[5]James Knowlton, "Definition of Picture," AVCR, XIV, No. 2 (1966).

[6]C. W. Morris, Signs, Language and Behavior (Englewood Cliffs, N.J.: Prentice-Hall, 1946).

[7]J. J. Gibson, "A Theory of Pictorial Perception," AVCR, II, No. 1 (1954).

depends on referents in the beholder's experience. Knowlton also develops categorizations of signs and referents plus a taxonomy of visual-iconic signs. In his categorization of signs, Knowlton perpetuates the basic distinction between iconic and digital signs. Iconic signs (photographs, drawings, paintings) resemble their referents in degrees varying from abstract (stylized line drawings) to realistic (three-dimensional colored movies). Digital signs do not resemble their referents; they are coded in symbol form such as letters and numerals. Knowlton's analysis of the iconic-digital categories extends to the use of one or the other in specific communications situations. In one instance a picture may be worth a thousand words, while in another one word may be worth a thousand pictures. He says that iconic signs give knowledge of the world by providing sensory data whereas digital signs give knowledge about the world by providing conceptual information.[8]

Knowlton's contribution to visualization theory is to extend the definition of visuals by developing a language for talking about pictures. Conway[9] hails Knowlton's effort as being basic to meaningful analysis of visual

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[8]James Knowlton, A Socio- and Psycho-Linguistic Theory of Pictorial Communication (Bloomington: Indiana University Division of Instructional Systems Technology, 1964).

[9]Jerome Conway, "Information Presentation, Information Processing and the Sign Vehicle," AVCR, I, No. 4 (1968), 405.

information presentation and is supported by Zettl[10] in the instructional television field who calls for the development of (1) a new television language to identify aesthetic variables, and (2) a taxonomy of these variables to facilitate systematic research. Fleming[11] contributes to the analysis of pictures through his elaboration of three elements of visuals--pictorial (iconic), verbal (digital), and design (e.g., arrows for emphasis and cue designation); he relates learning to visualization (illustrations in books) by developing taxonomies of behavior in terms of identifiable attributes of pictures. Moore[12] also proposes a taxonomy in the perceptual-motor domain to interpret information extraction at five levels: (1) sensation, (2) figure perception, (3) symbol perception (including the ability to identify letters and digits), (4) perception of meaning, and (5) perceptive performance. Moore defines perception in Gibson's sense of the perceiver actively attempting to adapt to his environment by selecting features from among sensory stimuli to reduce uncertainty.

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[10] H. Zettl, "The Study of Television Aesthetics," Educational Broadcasting Review, II, No. 1 (1968), 44.

[11] Malcolm Fleming, "Classification and Analysis of Instructional Illustrations," AVCR, XV, No. 3 (1967), 247.

[12] Maxine Moore, "The Perceptual-Motor Domain and a Proposed Taxonomy of Perception," AVCR, XVIII, No. 4 (1970), 408.

The desire for increased understanding of visual communication has kindled interest in visual literacy. Whereas literacy has by convention been a verbal concept, the ability of visualization to communicate is now being emphasized in terms of message presentation and reception. The acknowledged father of visual literacy, John Debes,[13] has contributed to the understanding of visuals by the development of characteristics of a visually literate person and a hierarchy of visual skills.

Related to the definition of pictures is a study by McCormick,[14] a human factors engineer, who compares the channel effectiveness of sight against hearing. He elucidates characteristics of the visual channel as follows: spatial in nature (excepting TV and motion pictures), simultaneous presentation, good referability, numerous dimensions in information coding, restricted flexibility and advance coding, fast rate of transmission, versatility, less attention-demanding, and less resistant to fatigue (p.427).

Critical Variables in Visual Instruction

Current research in visualized instruction is questioning existing theories. One group of theories being

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[13] John Debes, Visual Literacy Proceedings (New York: Pitman Publishing Corp., 1970).

[14] E. J. McCormick, Human Engineering (New York: McGraw-Hill, 1958).

scrutinized are those classified by Dwyer as the "Realism Theories," which contend that learning proceeds from concrete-to-abstract and that "an increase in realism in the existing cues in a learning situation increases the probability that learning will be facilitated."[15] Included in the realism theories are Dale's cone of experience, Carpenter's sign similarity hypothesis, Morris's iconicity theory, Severin's cue summation theory, Gagné's hierarchy of learning, plus "Gibson's (1954) projective-conventional continuum, Osgood's (1953) more detachable-less detachable continuum, and Knowlton's transparency-opacity continuum."[16]

Specifically what is being examined is the degree of detail in visuals necessary to instruct. A leading critic of the realism theories is Travers who gains support from researchers investigating the ability of the central nervous system to process visual information. Travers hypothesizes that learners can assimilate only a limited amount of information and that highly detailed pictures contain information overload and extraneous cues that interfere with learning; he contends that visual information is stored in the nervous system in a form similar to line drawings. To use the sight channel effectively, he implies that visuals should be reduced in complexity and only

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[15] Dwyer, op. cit., p. 4.

[16] Loc. cit.

relevant cues should be presented. Travers et. al. state, "Merely confronting a person with stimuli identical to those emitted by the real environment is no guarantee that useful information will be retained."[17]

In support of Travers' contention, Dwyer cites the studies of Broadbent,[18] Jacobson,[19] Livingston,[20] and Attneave[21] who say that in processing information the central nervous system must filter relevant detail from complex realistic stimuli. The implication for visualization is that by pre-filtering detail by visual design, by providing cues to important aspects of visual messages, instruction can be made more effective. Or, as Dwyer expresses it, "Because excesses of realism may actually interfere with the effectiveness of visual materials, it is essential that we attempt to identify those characteristics

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[17] R. M. W. Travers; M. C. McCormick; A. D. Van Mondrans; and F. E. Williams, Research and Theory Related to Audiovisual Information Transmission (Salt Lake City: U. of Utah, Bur. Educ. Res., 1964), p. 119.

[18] D. E. Broadbent, Perception and Communication (New York: Pergamon Press, 1958).

[19] H. Jacobson, "The Informational Capacity of the Human Eye," Science, CXIII, (1951), 292-3.

[20] R. B. Livingstone, "Central Control of Afferent Activity," in H. H. Jasper et. al. (ed.) Reticular Formation of the Brain (Boston: Little, Brown, 1958), pp. 177-85.

[21] F. Attneave, "Some Informational Aspects of Visual Perception," Psychological Review, LXI (1954), 183-93.

within visuals that will facilitate student achievement of specific kinds of learning."[22]

Dwyer's extensive research of visual instruction deals primarily with the problem of detail. He experiments with a variety of illustrations (simple black-and-white line drawings to realistic color photographs) presented via various media forms (printed programmed instruction, slide-tape, television); his subjects are high school and college students. Dwyer concludes that where the method of presentation involves fixed pacing, as in television and slide-tapes, detailed pictures are not as effective as less detailed. However, where the pacing is controlled by the learner as in programmed instruction, realistic visuals are more effective.[23] In other words, method of presentation and contact time affect the type of visual that will facilitate students' achievement of instructional objectives.

While Dwyer, Travers and others have found the amount of detail in instructional visuals to be a major variable, Levie and Dickie[24] report that the most common finding from their search of the literature is one of no difference (p.33). However, they cite only two studies in support of

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[22]Dwyer, op. cit., p. 7.

[23]Ibid., p. 82.

[24]W. H. Levie and K. E. Dickie, "The Analysis and Application of Media," in R. W. M. Travers (ed.) Second Handbook of Research on Teaching (Chicago: Rand McNally, 1973).

their generalization. Levie and Dickie summarize the detail issue by stating that instruction through visuals is a selective process: "The process of interpreting a picture entails a sampling procedure, and the communicator's intent will be achieved only if the viewer gets the 'right' sample" (p. 37).

Other studies have approached the problem of visualized instruction from the perspective of combining visual with audio to produce the optimal learning presentation. Among their considerations is the learner's capacity to process sensory data and the effects on learning of message design. Information processors generally recognize that there is a finite capacity of the individual to assimilate sensory data. Processing depends on individual differences of the receivers and the nature of the processing system. There is general acceptance that information from only one channel at a time can be processed by the central nervous system.[25]

Results from the effects of combining visual with audio for instructional purposes are varied. Hoban and VanOrmer[26] report a general advantage of sound plus picture

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[25]E. Tulving and P. H. Lindsay, "Identification of Simultaneously Presented Simple Visual and Auditory Stimuli," Acta Psychologica, XXVII, (1967), 101-9.

[26]C. F. Hoban and E. B. VanOrmer, Instructional Film Research 1918-50 (Port Washington: Special Devices Center, NAVEXOS P-977, 1950).

over single channel presentation in their review of films. May and Lumsdaine[27] support this conclusion. Hsai[28] finds a superiority of audiovisual when the two channels reinforce one another while keeping interference effects (noise) down. He also finds between-channel redundancy effective for young and low-ability students. Severin makes his support of audiovisual presentation contingent upon the nature of the cues presented in the message:

> Multiple-channel communications appear to be superior to single-channel communication when relevant cues are summated across channels, neither is superior when redundant between channels, and are inferior when irrelevant cues are combined (presumably because irrelevant cues cause interference between them.)"[29]

In testing the superiority of one channel over the other, Severin finds that for recognition purposes audiovisual is superior to either mode alone. Conway[30] contradicts this by concluding that visual alone is superior to audiovisual.

Levie and Dickie again summarize the varied findings by stating that "more learning may result from audiovisual presentation under certain conditions which are not fully

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[27] M. A. May and A. A. Lumsdaine, Learning from Films (New Haven: Yale University Press, 1958), pp. 150-67.

[28] Hower Hsai, "On Channel Effectiveness," AVCR, XVI, No. 3 (1968), 247.

[29] Werner Severin, "The Effectiveness of Relevant Pictures in Multiple-Channel Communications," AVCR, XV, No. 4 (1967) 397.

[30] Conway, "Information Presentation," p. 411.

defined or understood."[31] They also say that concern about single-channel information processing becomes a problem only when the rate of audiovisual presentation is too fast for learners to switch and assimilate the two-channel message.

Related to the above discussion is consideration of individual differences among learners, one of which is channel utilization efficiency; that is, in combined audio-visual presentations one channel may dominate depending on the learner.[32] Other individual differences include age (the effect of maturation) and preference. Levie and Dickie state that children from the fifth grade down learn better from the spoken language than from pictures (p. 35). This is contradicted by Hsai[33] and seriously questioned by Palmer,[34] the research director of "Sesame Street," who believes that attention is basically a function of display. Travers contends that student interpretation of visuals is a function of maturity. He cites support from Ames (1953), Elkind (1964), Piaget and Inhelder (1956) who studied children's perceptions of whole versus parts and their awareness

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[31] Levie and Dickie, op. cit., p.32.

[32] Ibid., p. 31.

[33] Hower Hsai, "Intelligence in Auditory, Visual, and Audiovisual Information Processing," AVCR, XVII, No. 3 (1969), 43-48.

[34] E. L. Palmer, "Research at the Children's Television Workshop," Ed. Broadcasting Rev., III, No. 5 (1969), 43-48.

of the concept of dynamism within still pictures. His conclusion is that "pictures are of doubtful value for communicating anything other than the simplest pieces of information to young children."[35] Travers also cites his own experimentation with students' preferences for one form of picture over another. He concludes that older students prefer more complex pictures although they may not learn more from them. Travers hypothesizes that "a child prefers the most complex presentation that he is able to organize perceptually."[36] Children also prefer large, colored pictures, while children and adults prefer motion to still pictures although they react the same emotionally to both.[37] Gropper[38] concludes that visuals can play an instructional role with young or low-ability students, particularly for the purpose of concept learning. There is general agreement that people have to learn to interpret or read pictures and that visual learning is a function of maturation.

Dwyer lists eleven educational or psychological characteristics of students to consider when using visuals: age, mental ability, learning style and attitude, cultural

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[35] R. M. W. Travers and V. Alvarado, "The Design of Pictures for Teaching Children in Elementary School," AVCR, XVIII, No. 1 (1970), 56.

[36] *Ibid.*, p. 59.

[37] Levie and Dickie, *op. cit.*, p. 36.

[38] George Gropper, "Learning from Visuals: Some Behavioral Considerations," AVCR, XIV, No. 1 (1966), 66.

factors, interest, motivation to learn, creativeness, verbal and conceptual ability, perception, prior experience and knowledge, and grade level (p. 95).

Motion as a factor in visualization is important to the study of controlled-scan television, a still medium. Comparisons of motion pictures to still pictures generally show no significant difference. Miller[39] finds no difference in affective response by students to pictures presented in motion and still form. Emotional reaction was measured by glavanic skin response. From their review of the literature, Chu and Schramm conclude that "moving images do not add significantly more to learning than still visual images do, unless the continuity of action is an essential part of the learning task" (p. 95).

Another critical variable in the design of effective visuals is the use of cues. Hoban[40] reports that devices such as arrows to indicate relevant information are effective in increasing learning. Dwyer investigates three methods of cueing television instruction and concludes that while cues are effective, they are not equally so. Dwyer's experimental procedure generally consists of five basic treatments

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[39]W. G. Miller, "Film Movement and Affective Response and the Effect on Learning and Attitude Formation," AVCR, XVII, No. 2 (1969), 172-81.

[40]C. F. Hoban, "The Usable Residue of Educational Film Research," New Teaching Aids for the American Classroom (Stanford: Stanford University, Institute for Communications Res., 1960), p. 107.

(oral presentation, simple line drawing, detailed shaded drawing, model, realistic photographs) and five criterial tests (drawing, identification, terminology, comprehension, total criterial). Within this context he tests cueing methods consisting of (1) simple arrows, (2) motion (the instructor physically motioning to relevant cues), and (3) questions (pertinent questions preceding the presentation of information). Dwyer concludes:

> The use of motion is not an effective cue when the presentation uses realistic visuals and the students are limited in the time they can interact with the visual information (pp. 41-2).
>
> The use of questions as cues in the more realistic visual displays is not effective. The use of questions to complement simple line drawings is effective for the criterial measures (p. 43).
>
> No method of cueing is particularly effective when students know criterial measures in advance (p. 45).
>
> When students do not know the nature of criterial measures in advance, the use of questions appears to be the most effective cueing device (p. 47).

The Application of Results to Instruction

Anderson introduces some practical considerations into the matter of visual design. He states that in mixed media presentations most of the information is contained in the verbal portion of the message and that television, for example, is not used as a visual medium, "but as a pipeline for whatever incidental activities accompany a primarily verbal communication."[41] Anderson argues that learning gains in many experimental studies are paper-and-pencil measures of cognition; rarely is information that is presented visually tested visually, and areas of learning other than cognition (e.g., problem-solving) are infrequently emphasized within visualized instruction. Anderson offers the following generalizations as gleaned from his review of literature:

> If the message and testing are verbal, then pictorial production treatment should be minimal (p. 50).
>
> Visuals should be carefully selected but need not be presented unless they provide relevant, nonredundant cues (p. 50).
>
> Use arrows and other production means to draw attention to relevant cues (p. 50).
>
> There is some substantiation for an interaction between information and visualization. Some content may be more suitable for visualization. Content areas that are composed partly or entirely of visual stimuli, where imagery can convey an abstract concept, where manual tasks are involved, or where the information is primarily visual seem to be suited to visualization (p. 51).

Dwyer offers the most specific conclusions in the application of visuals to instruction. In essence they are:

> The use of visuals does not automatically improve learning.
>
> All types of visuals are not equally effective. Type of visual is dependent on type of information to be conveyed.
>
> The medium (television, slides) affects the type of visual. Identical visual illustrations are not equally effective when used for externally paced and self-paced instruction.

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[41] Charles Anderson, "In Search of a Visual Rhetoric for Instructional Television," AVCR, XX, No. 1, (1972), 57.

> Time is an important variable for student interaction with visuals. (More time is required for highly detailed visuals.)
>
> The same visuals are not equally effective for students in different grade levels.
>
> Student perceptions of the value of different types of visual illustrations are not valid assessments of their instructional effectiveness; that is, aesthetically pleasing visuals may be deceptive in their instructional value.
>
> The realism continuum for visual illustrations is not an effective predictor of learning efficiency.
>
> The use of cues facilitates visual instruction depending on the situation (pp. 89-90).

Gropper finds that visualization makes concept learning easier and aids generalization across modes. Specific roles he identifies are cueing responses, reinforcing responses, and serving as examples for discrimination.[42] Gropper supports active response by the learner to visual presentations as part of learning strategy, but emphasizes that successful use of visuals for instruction depends on a critical analysis of purpose and task before employment.

To this end--that is, toward a systematic approach to the use of visuals in instructional television--Trohanis and DuMonceau have authored "Factors to Consider When Designing Television Pictorials," (EBR,V, No.1, 1971)pp. 35-42. The authors suggest seven interconnected components: (1) learner traits, (2) types of learning, (3) television

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[42] Gropper, "Learning from Visuals," p. 66.

attributes, (4) learning objectives, (5) program preparation, (6) telecast and viewing, and (7) feedback and evaluation, to be considered through three phases of development: (1) planning, (2) implementation, and (3) evaluation. While the authors discuss only the first five components (the planning phase), their discussion reflects a comprehensive knowledge of visual literature[43] and represents a practical attempt to operationalize research findings.

Television Legibility

Research on legibility is legion. Legibility has traditionally been studied by printers, opthalmologists, psychologists, and human factors engineers (designers of instruments, dials, and more recently electrical systems displays such as computer display via cathode ray tube (CRT) and radar-type display situations). Most research on legibility has occurred in print (newspapers, books) and print-related areas (coded information displays such as dials and scales).

Two compilations of abstracts document the development of legibility research in the United States during this century: (1) Legibility, the National Project in Agricultural Communications, Michigan State University, (211 abstracts to the mid 1930's); and (2) Legibility of Alphanumeric

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[43]Trohanis has also written "ITV Pictorialism: A Bibliography," Ed. Broadcasting, II, No. 11 (1970), citing 56 key studies pertinent to visualization.

Characters and Other Symbols I and II, a reference handbook of the National Bureau of Standards, U. S. Government, 1965. The latter cites only two studies of television legibility; the former, none. In addition, the results of legibility research have been assimilated in textbooks such as Ernest J. McCormick's Human Factors Engineering (New York: McGraw-Hill, 1964) in an attempt to put theory into practice.

Traditional research has concentrated on physical factors affecting legibility using printed letters and numbers (alphanumerics) as stimuli. The influence of each factor has been measured in terms of accuracy and speed of identification, the theory being that those alphanumerics most accurately and quickly identified are most legible. From these studies certain classical legibility factors have been identified which are generalizable from print to non-print areas. Shurtleff[44] summarizes these factors as: (1) symbol brightness and brightness contrast, (2) ambient illumination, (3) symbol exposure time, (4) symbol spacing, (5) symbol size, (6) stroke width, (7) symbol style and geometry, and (8) viewing angle. New physical factors of legibility related to mechanical and electrical components

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[44]D. A. Shurtleff, "Part 1, Classical Factors in the Legibility of Numerals and Capital Letters," in Design Problems in Visual Display (New Bedford, Mass: Mitre Corp., ESD TR-66-62, 1966).

have emerged in the past 25 years with the evolution of modern display equipment, including television.

Formal studies of television legibility have occurred in three basic areas: (1) electronic information display systems, (2) commercial broadcasting, and (3) instructional television. Of these three, the most fruitful literature occurs in the systems application of television.

Results from research by commercial broadcasting have limited application to this study in that both the properties investigated and the methods of research are inappropriate for generating standards of legibility for use by group viewing of ITV. Shurtleff[44] states that of thirty studies reviewed by him, none was concerned directly with legibility; most were investigations of viewers' subjective evaluations of some aspect of picture quality, such as the perceptibility of powerline interference. Evaluation procedures required viewers to express their opinions or judgements "about the degree of impairment of picture quality caused by the factor of interest" (p.41).

A partial exception to Shurtleff's generalization is a recent (1970) study by CBS Laboratories of Stamford, Connecticut, to develop a new type font generated by a synthetic character device for television display. The

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[44] D. A. Shurtleff, "Studies in Television Legibility--A Review of the Literature," Information Display, IV (Jan./Feb., 1967), 40-45.

main advantage of the electronic generator is its capability of instantaneous superimposition of a printed message on the TV screen. However, existing computer character generators pose video problems:

> There are available computer-generated, but not video-compatible, character generators. These are point-to-point CRT displays of alphanumerics, which, while electronically generated, still require the use of a video camera for scan conversion. These letter devices exhibit the halation at the top of the light-scale and the blooming at corners that are the inherent problems of superimposition.[45]

CBS's answer to the problems of halation and blooming was to compensate graphically for the display limitations of the electronic generator. As explained by Baron, "CBS undertook to design a system which would synthetically reproduce a graphic arts style with sufficient resolution to be compatible with the superimposition technique."[46] The Graphic Arts Department under Rudi Bass created a modified print style called "CBS News 36" or "Vidifont" which met prescribed system, font design, and size requirements. Development of the new font involved comparing displays of existing styles of type faces in a formative process of evaluation and design. Bass describes the procedure:

> We prepared slides and telops of all-capital alphabets and superimposed them over photographic slides simulating a broadcast . . . . Photographs were

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[45] S. N. Baron, "A Graphic Quality Character Generator for Television Titling," Journal of the Society of Motion Picture and Television Engineers, XXC (February, 1971), 78.

[46] Ibid., p. 78.

> taken off a studio monitor and photographic enlargements made. These were copied and further enlarged to show large-screen reproduction and to simulate, as far as it was possible, the further loss in definition from the studio to the home screen.[47]

Summative testing of the new font for legibility is not described by either Bass or Baron, but it appears that design decisions were based on visual judgements by the experimenters of presence or absence of the effects of halation, blooming, bleeding, decay--those problem areas inherent in superimposition.

An air traffic control system (SPANRAD) adopted a similar approach to legibility. Rowland and Cornog of Courtenay Company hypothesized that a print font could be designed unique to television that would compensate for system influences on the form of displayed symbols. Because their method of development relied on subjective judgement, Shurtleff and Owen[48] undertook an experimental comparison of the SPANRAD font with the more conventional Leroy font to determine if the new design really was more legible. The results showed no statistical difference.

Literature on legibility from the instructional television area reflects two levels of concern: (1) commercially published standards which give no bases for their

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[47] Rudi Bass, "The Development of CBS News 36," The Journal of Typographic Research, I, No. 4 (1967), 364.

[48] D. A. Shurtleff, "Part II, Factors in the Legibility of Televised Displays," in Design Problems in Visual Display (New Bedford, Mass: Mitre Corp. ESD TR-66-62, 1966), 34.

recommendations, and (2) experimental studies which quantify results and detail procedures for testing. Examples of the first type include Eastman Kodak publications--"Art-Work Size Standards for Projected Visuals " (pamphlet No. S-12, 1957A), "Slides and Opaques for Television" (S-5, 1957 B), "Legibility Standards for Projected Materials" (S-4, 1965)--and Educational Facilities Laboratories, Inc., "Standards of Legibility."[49] Standards cited by the last two publications indicate evidence of knowledge of results of recent experimental studies of television legibility. Their figures are compatible with each other and consistent with research, whereas two earlier Kodak studies showed gross inconsistencies as critiqued by Kasten.[50] Among the earliest educators to concern himself with viewing standards for instruction was Philip Lewis.[51] However, his use of commercial programs for viewer stimulus and his reliance on subjective judgements cause Seibert _et al_[52] to question his

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[49]Dave Chapman and Frank Carioti, "Seeing, Hearing and Learning," from Design for ETV, Planning for Schools with Television (New York: Educational Facilities Labs., 1968) 31-40.

[50]Duane Kasten, "A Study of Five Factors Influencing the Legibility of Televised Characters," (Dissertation Purdue University, 1960), p.2.

[51]Philip Lewis, "TV Takes a Test," Educ. Screen, XXIX, (1950), 196-98.

[52]Warren F. Seibert, Duane Kasten, and James Potter, "A Study of Factors Influencing the Legibility of Televised Characters," Journal of the Society of Motion Picture and Television Engineers, LXVIII (July, 1959), 467.

generous standards. For example, Lewis suggested that up to 75 students could view a 16-inch classroom receiver at distances up to 23 feet.

The most extensive statement of legibility standards for ITV to date is by G. F. McVey[53] who identifies basic legibility factors, suggests standards for each, and urges users of ITV to field test materials in actual classroom settings. He does not describe a specific procedure for field testing. McVey's guidelines for teachers and instructional media personnel draw on experimental research in the information display area.

Two studies stand out as an example of the second type of instructional television literature study. One is by Seibert, Kasten, and Potter[54] who experiment in a classroom-type setting with 36 volunteer college students as subjects. (This study is reported in two documents, (1) an article in the Journal of the Society of Motion Picture and Television Engineers, and (2) a doctoral dissertation by Kasten.) Five factors influencing legibility are tested on live, closed-circuit television: (1) symbol size, (2) viewing distance, (3) viewing angle, (4) contrast, and (5) elapsed time. The experimental design is a factorial

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[53]G. F. McVey, "Legibility and TV Display," Educ. Television, II, No. 11 (1970), 18-23; and "Television: Some Viewer-Display Considerations," AVCR, XVIII, No. 3, 277-90.

[54]Seibert et al, op. cit.

of the five variables; the statistical model is analysis of variance. The 36 subjects (ranging in age from 17 to 35 and screened for visual acuity on a Bausch & Lomb Ortho-Rater) were divided into two groups of 18 for viewing from two separate classrooms (television studios simulating a classroom setting). Each subject was randomly assigned to a viewing station from one of six distances at one of three viewing angles; distances from the screen were 6, 9.8, 13.6, 17.4, 21.2 and 25 feet, while viewing angles were 0, 19 and 38 degrees (0 was an angle running perpendicular to the face of the television receiver). Symbol stimuli were sets of four-character alphanumerics in Futura Medium font, upper case, in four sizes of 60, 48, 36 and 24-point type (a total of 252 visuals). Contrast conditions (figures to background) were black-on-white, white-on-black and white-on-medium gray. The elapsed time variable was tested by showing the stimuli in three periods of approximately 15 minutes each, with five minute "filler" periods between; the three display periods provide the data for the study.

Description of Experimental Conditions for Seibert et al:

Symbol brightness: not stated
Background brightness: not stated
Brightness contrast: not stated
Ambient illumination: 25 to 38 ft.-candles
Symbol-background relation: L/D and D/L
Symbol style: Futura Medium
Horizontal spacing: 50 per cent of symbol height
Symbol width: 77 per cent of symbol height

Symbol stroke-width: 17 per cent of symbol height
Number of symbols: 28; I,O,R,1,2,3,7 and 0 omitted
Number of subjects: 36 college students
Visual characteristics of subjects: 20/20
Viewing distance: 72 to 300 inches
Viewing angle: 0, 19 and 38 degrees
Monitor size: 24 inches

The second study is by an engineering psychologist, Alan S. Neal,[55] at the IBM Advanced Systems Division Laboratory, Los Gatos, California. He investigates four variables affecting legibility of television displays for the purpose of generalizing results to classroom viewing situations. The four variables are: (1) scan lines per character height, (2) bandwidths of 2.5, 3.1, and 4.0 megaHertz, (3) visual angle, and (4) viewing angle. Neal's main concern is with the effect of the quality of television systems on classroom instruction. He evaluates quality by having individual subjects view sets of videotaped alphanumerics and measuring their accuracy of identification. Single subjects (twenty female typists ranging in age from 18-39 and pre-screened for normal vision) were tested in a laboratory setting seated in front of a 14-inch television monitor. Subjects were required to identify successive displays of eight rows of seven characters each by typing them on an input/output typewriter connected to a computer. Typographical errors could be corrected by the subjects. Fourteen combinations of vertical resolution (at bandwidths

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[55]Alan S. Neal, "Legibility Requirements for Educational Television," Information Display Journal, V, No. K (1967).

of 2.5, 3.1 and 4.0 mHz) and visual angle (ranging from 3-14 minutes of arc) were tested at distances of 10, 15 and 23 feet. Five conditions at 3.1 bandwidth were tested at viewing angles of 10, 30 and 40 degrees off perpendicular. Testing time per subject totaled five hours including an extensive practice session and frequent rest periods. Character sets were randomly generated. Character font was Manifold (bold, sans serif), half upper case letters and half numbers. The computer automatically tallied legibility (per cent of characters accurately identified) and average throughput (the speed of characters identified per minute). The statistical model was analysis of variance.

Description of Experimental Conditions for Neal:

Symbol brightness: 2 ft.-lamberts
Background brightness: 20 ft.-lamberts
Contrast: D/L symbol-background relationship
Ambient illumination: not stated, but glare on screen was reduced by use of a circular polarized screen over the monitor face, and use of nonreflective black paper on walls.
Symbol style: Manifold, upper case
Stroke width: bold
Symbol height: stated in visual angles 4.0, 4.7, 6.3, 8.1, 14.3
Spacing: standard row spacing of pica or 12-point type
Symbol exposure time: variable depending on subject
Number of symbols: 26 letters, 10 numbers
Number of subjects: 20, ages 18-39
Visual characteristics of subjects: 20/20
Viewing distances: 10, 15, 23 feet
Viewing angles: 0, 10, 20, 30, 40 off axis
Monitor size: 14 inches
Scan lines: 525
Signal to noise ratio: peak to peak/RMS 40.8 db.
Bandwidths: 2.5, 3.1 and 4.0

The most extensive literature in factors affecting television legibility has occurred in the area of electronics information display systems. In particular the military's interest in topics such as target identification has led to detailed investigation into quick and accurate information display. Government contracts have provided funding for experimentation.

The information-display data most applicable to determining standards for instructional television come from a series of studies headed by Donald A. Shurtleff[56] on display-symbol legibility, commissioned by the U. S. Air Force. Included in reports of his studies is an exhaustive review of relevant literature. Shurtleff's review is organized around factors which affect the legibility of televised symbols, such as: (1) vertical resolution, (2) video bandwidth, (3) quality of television equipment, (4) symbol style, (5) symbol stroke-width, (6) symbol exposure time, (7) visual angle, (8) viewing angle, (9) direction of contrast, and (10) surrounding brightness.

Shurtleff's basic experimental technique is comparable to the procedures of Seibert and Neal. Conclusions depend on objective recording of quantifiable data. Shurtleff randomly assigns single subjects to given experimental conditions, displays alphanumerics on a television screen, and

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[56] D. A. Shurtleff, Design Problems in Visual Display (New Bedford, Mass.: Mitre Corp., 1966).

requires subjects to identify the individual characters. Unlike Seibert and Neal, Shurtleff requires subjects to identify displayed symbols vocally rather than in writing; on occasion he uses 945-scan line TV instead of 525.

Visual Angle

In all studies, given video resolution, visual angle (a function of symbol size and viewer distance) has been the most critical variable of legibility. According to Seibert et al[57] the minimal visual angle for maximum identification (over 93 per cent) is 10 minutes of arc. Neal[58] concludes that for 95 per cent accuracy, eight minutes of arc is minimum. Shurtleff, Marsetta, and Showman[59] suggest a minimal visual angle of 13 minutes. Shurtleff et al further indicate that there should be an 11 per cent increase in visual size if the edges of the screen are used for display purposes, because resolution at the edges of the television screen is inferior to that at the center. McVey[60] suggests that for standard broadcast quality, minimum visual angle for individual viewing should be 10 minutes of arc, for group viewing in a narrow sector 12 minutes, and for wide-angle viewing 15 minutes. Elsewhere, McVey states, "The

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[57] Seibert et al, op. cit., p. 470.

[58] Neal, op. cit., p.43.

[59] Shurtleff, "Part II," Design, p. 25.

[60] McVey, "Legibility," p. 19.

generally recommended symbol size for television is 30 minutes of arc (a symbol measuring 1" on the picture tube as seen from ten feet)."[61]

Kodak[62] recommends a minimum visual angle of nine minutes or a symbol size of .31 inches at a viewing distance of approximately ten feet. The maximum viewing distance/minimum symbol size recommended by the Educational Facilities Laboratories[63] is identical to that of Kodak.

The Society of Motion Picture and Television Engineers[64] expresses size recommendations in terms of a minimum percentage of the scanned height of a screen, namely 4.5 per cent. The visual angle complement is approximately 19 minutes of arc.

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[61] G. F. McVey, "Where Do We Sit?" Educ. TV, I, No. 14 (1969), 25.

[62] Legibility Standards of Projected Materials, (Rochester, N.Y.: Kodak Pamphlet No. S-4, 1965), p.4.

[63] Chapman and Carioti, op. cit., p. 39.

[64] Baron, op. cit., p. 80.

TABLE 2-1.--Minimum Visual Angle for Television Viewing as Recommended by Selected Sources.

Source	Minimum Visual Angle in Minutes	Approximate height in inches from 10 feet
Seibert *et al*	10	.33
Shurtleff *et al*	13	.45
Neal	8	.30
McVey	10 individual 12 narrow sector 15 wide sector	.33 .40 .53
Kodak, Ed. Fac. Lab.	9	.31
Society of MPTE	(19)	.66

Brightness Contrast

Studies involving contrast have tended to deal primarily with high contrast conditions, either black (dark/D) on white (light/L) or light on dark (L/D). Seibert *et al*[65] include a third contrast condition, white on medium gray (poster board #1228), but do not state any of their contrast conditions in measured symbol and background brightnesses (foot-lamberts). Seibert concludes that high contrast conditions are superior to white on medium gray and that D/L is slightly preferable to L/D. However, in a second study,

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[65] Seibert *et al*, *op. cit.*, p. 468.

unpublished, Seibert[66] concludes that the reverse polarity is superior, that L/D produced greater accuracy than D/L. This latter conclusion concurs with findings by Jackson[67] who states that alphanumerics should always be L/D.

A study by Kelly[68] on high contrast conditions explores the effects of ambient illumination on direction of contrast. (Most television displays are viewed under conditions where external light surrounds the viewing screen.) His conclusions are that L/D symbol-background contrast results in more accuracy under low ambient illumination, while D/L symbols are identified more accurately under low ambient illumination, while D/L symbols are identified more accurately under medium and high conditions. McVey supports Kelly's conclusions and recommends that "Where there is a choice, labels, captions, titles, etc., should be L/D; long statements and text, D/L."[69] He further suggests that if the method of visual display is superimposition, then the nature of the background will dictate the direction of symbol contrast. McVey advises that "A contrast ratio between 3:1 and 10:1 is generally recommended for

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[66] W. G. Seibert, "The Legibility of Televised Visuals: A Study of Signal Bandwidth and Other Factors," (unpublished study, Purdue University, 1964), 9 pp.

[67] Robert Jackson, Visual Principles for Training by Television (Port Washington, N.Y.: U.S. Naval Training Device Center, Human Eng. Rept. SDC 20-TV-2, no date).

[68] Shurtleff et al, "Part II," Design, pp. 41-2.

[69] McVey, "Legibility," p. 21.

television displays. This represents between five and ten steps on a standard ten-step gray scale."[70]

Kodak[71] recommends using black symbols on gray or white or white symbols on gray. It mentions using a gray with about 25 per cent reflectance for background to accommodate both black and white symbols. Educational Facilities Laboratories[72] like Kodak, recommends either black symbols on light gray, or white on dark gray.

A phenomenon noted by various sources is the effect of irradiation.[73] That is, in high contrast conditions white letters on black appear to spread into their background while black letters on white appear thinner than their actual width. This complicates precise comparison between high contrast conditions. It also influences stroke width of symbols in that dark letters on white require a wider stroke than do white letters on dark.

Viewing Angle

Considerable attention has been paid to viewing angles for groups, particularly for motion picture display. Less attention has been paid to television viewing. Viewing angle is a concern for instructional television because

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[70] Loc. cit.

[71] Legibility Standards, p. 7.

[72] Chapman and Carioti, op. cit., p. 39.

[73] McCormick, Human Factors Engineering, p. 164.

students sitting at too loblique an angle to the screen will not be able to see the two-dimensional image clearly and thus not learn as well. This situation is generally referred to as the "cone effect."[74]

Shurtleff's review of the literature in the non-television area leads him to this conclusion generalizable to television:

> It appears that, for all practical purposes, observers sharing a common display can be placed at angles up to 45 degrees from the normal line of sight at about the same distance as that required for the normal line of sight.[75]

Neal tests viewers at five angles, 0 degrees (a line drawn perpendicular to the screen), 10 degrees off axis, 20 degrees, 30 degrees, and 40 degrees. His conclusions are:

> Under conditions where vertical resolution and visual angle give high legibility (better than 90 %) at 0 degrees off axis, there is no decrement in legibility until the off-aix angle becomes 40 degrees. Under less favorable conditions, the effect of the off-axis angle is more severe, reducing the legibility even at 20 degrees.[76]

From this findings, Neal recommends that viewers should sit in a cone-shaped area fanning out from the screen within 30 degrees of either side of a line drawn perpendicular to the screen.

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[74] Chu and Schramm, Learning from Television, p. 39.

[75] Shurtleff, "Part I," Design, p. 93.

[76] Neal, op. cit., p. 42.

Seibert et al[77] conclude that viewing angles up to 19 degrees off axis do not affect legibility, but that between 19 and 38 degrees there is a loss in accuracy of identification.

McVey[78] suggests a cone-shaped viewing area but within 45 degrees of either side of the screen. Within the cone he maps out four categories of viewing: optimum, acceptable, acceptable for high resolution systems, and acceptable when symbol size is adequate. In addition, McVey attends to the vertical viewing angle, recommending that viewing involve no more than an inclination of +15 degrees or less than a declination of -24 degrees.

In a highly complex engineering study, Weiss describes a viewing space within which an audience can, for all practical purposes, legibly see alphanumeric displays. His calculations include consideration of horizontal viewing angles, and the horizontal plane at which most viewers sit. Weiss suggests that audience volume (the space which permits acceptable viewing) varies with the amount of information presented on the screen. He states, "If the screen is filled to capacity, the display can only be read from a single point.· To accommodate a finite audience, the screen

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[77]Seibert et al, op. cit., p. 471.

[78]McVey, "TV: Some Viewer-Display Considerations," p. 284.

must be utilized substantially below capacity."[79] Weiss also suggests that the greatest number of viewers can be accommodated by tilting the screen so that its center intersects the audience at eye level at a distance of half the maximum visual range. In effect, Weiss recommends that space for group viewing of television is football shaped. The dimensions of the shape are determined mathematically by such factors as screen size, aspect ratio (the 3:4 relationship of height to width of a TV screen), symbol size, and display capacity.

Most textbook references recommend that students in a classroom view television from no more than 30-45 degrees to the left or right of the screen. Educational Facilities Laboratories[80] recommends not more than 45 degrees off axis and less when images are of a highly critical nature. Hayman[81] concludes that viewing angles over 40 degrees affect learning. Generalizations from motion picture viewing to television tend to be more conservative, suggesting a viewing angle no more than 30 degrees off axis (Kodak, U. S. Navy, Office of Education). Differences between the 30 degree angle for film and the 45 degree angle for television

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[79] Helmut Weiss, "Capacity and Optimum Configuration of Display for Group Viewing," Information Display, (Nov./ Dec., 1966), 30.

[80] Chapman and Carioti, op. cit., p.33.

[81] J. L. Hayman, Jr., "Viewer Location and Learning in Instructional Television," AVCR, XI (1963), 186-7.

suggest a relationship between viewing angle and screen characteristics; the film screen has the image projected onto it while the television screen projects the image from it. The apparent ambiguity of visual angle has caused Milton Patrie to satirize the situation in an article titled, "How Does It Look from Where You Sit?"[82]

Summary

That television can teach is well documented by existing research. The attention of current research in instructional television is focusing on other problem areas including the relationship of the medium *per se* to instruction and the relationship of types of visuals to instruction.

A theoretical foundation is emerging from video research forming a base from which more meaningful studies can develop. To date, theoretical research has attempted to define visuals, and structure and categorize their functions and applications within instruction. A contemporary leader in this theoretical area is James Q. Knowlton of Indiana University who builds on the earlier works of Gibson and Morris.

Current research also is examining specific variables related to visualized instruction such as the use of motion and cues, but as researchers delve into specific variables

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[82]Milton Patrie, "How Does It Look from Where You Sit?" *Audiovisual Instruction*, XI, No. 3 (1966), 186-7.

they often raise more questions than they answer. For example, Dwyer offers experimental proof of the superiority of simple, abstract line drawings over complex, realistic photographs in certain learning situations thereby challenging Dale's long-standing realism theory (cone of experience). Practitioners are often left in a quandary as to which advice to follow when such critical variables as "the amount of detail necessary in a picture to teach" and "the effect of maturation on pictorial perception" yield conflicting results. It appears that during this formative phase of research into visualized instruction a major benefit to practitioners is simply to identify specific variables of visual design so that they can be incorporated into learning considerations.

From the growing amount of literature on visualization in instruction, Anderson, Gropper, Dwyer, and Trohanis attempt to summarize generalizations applicable to video media. Most conclusions warrant testing within each individual medium.

Literature in the area of legibility of televised messages for use in classroom instruction is very limited. However, research on legibility of printed materials is legion.

Of three basic sources of research on television legibility, namely education, commercial broadcasting, and information display systems, the latter is most productive. From education, two experimental studies stand out: (1) Seibert, Kasten, and Potter who tested five factors of legibility using 35 college students as subjects, and (2) Alan S. Neal who tested four variables using individual female typists as subjects. In addition, organizations such as Kodak and the Educational Facilities Laboratories, Inc., suggest standards of legibility. Another source, G. F. McVey of Wisconsin, outlines the most comprehensive set of guidelines for television display in the classroom. Commercial broadcasting offers few relevant suggestions regarding television legibility. By contrast, information display technologists, particularly those associated with the military, report numerous studies of television legibility applicable to systems operators. Shurtleff is the major researcher and author in this field.

In all television legibility studies, size of image and brightness contrast emerge as the leading variables affecting legibility. Viewing angle is treated in some studies, notably Seibert et al. Results of the studies, although not identical, do suggest reasonable guidelines for users that should be validated within individual systems.

It is intended that this study will extend the literature on visualized instruction and legibility by developing guidelines for the use of visual materials on a new video broadcast medium, controlled-scan television. In effect, standards of graphic presentation of messages will be prescribed in advance of CSTV being used as an instructional medium. This study will also add a new level of subjects (upper elementary students) to studies of television legibility and a new experimental setting, namely an actual classroom to which the CSTV signal will be broadcast on-air.

CHAPTER III

DESIGN OF THE STUDY

Introduction

This was an exploratory study to develop guidelines for the selection and production of visualized instructional materials for use on controlled-scan television in a classroom setting. Development of the guidelines was based on data derived from an experimental determination of legibility standards for this new medium. Visual angle (size), brightness contrast, and viewing angle were examined as independent variables affecting legibility. Legibility was operationalized by upper elementary school students viewing and identifying sets of characters displayed on a television screen. The accuracy of their scores represented the reading of legibility.

This study was designed to meet the following criteria set by Shurtleff[1] for studies in television legibility: (1) the study was concerned with the legibility of printed characters, (2) subjects were actually required to identify symbols, not just express opinions about their clarity, (3) viewers were screened for visual acuity, and (4) the

[1] D. A. Shurtleff, "Studies in Television Legibility--A Review of the Literature," Information Display, IV (Jan./Feb., 1967), 40-45.

conditions under which the experiment was conducted were recorded in detail.

In this chapter, the sample subjects, stimulus material, equipment and facilities, experimental conditions, instrumentation, procedure, research hypotheses, experimental design and analysis are described.

The Sample

The sample of subjects consisted of 72 grade five and six students of an elementary school in Flint, Michigan. Sixty-six subjects were in grade six, six in grade five. Of the 72 subjects, 41 were boys. Ages ranged from 10 to 13; two were 10 years of age, 29 were 11, 38 were 12, and three were 13. The selection of primarily grade six students complemented the level of subjects being tested in a Title III study by WFBE-FM, the Flint public broadcast (education) station.

The subjects' school lay within broadcast range of WFBE-FM, the station from which the controlled-scan TV signal would be transmitted to serve Flint schools. Choice of the school was decided by the Research and Testing Department of the school system so that this study would not overlap or duplicate subjects of the WFBE project.

The students were screened for visual acuity on the Snellen 20/30E Symbol test.[2] Those possessing normal or corrected vision qualified as subjects. Of the total 94 grade six population in the school, 74 met the acuity qualifications. A support group from grade five was screened as replacements for grade six subjects in case of absenteeism. Six grade five replacements were used.

Screening of the subjects for perceptual impairments was considered but not undertaken due to the lack of a recognized appropriate instrument and lack of agreement on interpretation of results when perceptual analysis is attempted.[3] Also, extending the population to the secondary school level was considered by rejected. It was the judgement of Dr. Richard Ball, opthalmologist and research associate of the Department of Psychology, Michigan State University, that the effect of maturation on perception of symbol displays (digital signs) had stabilized by fifth grade. Eye examinations and previous studies to determine legibility standards have been based on this premise.

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[2] Administrators Manual for Vision Screening Programs - Preschool and School (Lansing, Mich.: Vision Section, Bureau of Maternal and Child Health, Michigan Department of Public Health), p. 14.

[3] In consultation with Dr. Richard Ball, opthalmologist and research associate, Department of Psychology, Michigan State University, and Edmund Radke, Vision Section, Michigan Department of Public Health.

Subjects were randomly assigned to one of 12 groups of six students each. Within each group the subjects were further randomly assigned to viewing angle, two to each angle.

Stimulus Material

Materials required for presentation of the stimuli were 30 sets of black printed characters in four separate sizes plus three separate backgrounds of different values/ shades of the television gray scale.

Each display set consisted of five, four, or three figures randomly chosen from among 70 characters including inverted letters and numbers. (See Appendix A.) Each character was used at least once but no more than twice. The 30 sets were divided into three sections of ten sets each, with each section consisting of six sets of five symbols, two sets of four symbols, and two sets of three symbols, a total of 44 symbols per section. The order of presentation of the sets was randomized within each section; sections corresponded to contrast conditions during presentation.

The alphanumerics used in the visuals were Chartpak black transfer letters and numbers in Futura Medium (upper case) a simple Gothic style sans serif. The characters conformed to recommended height-to-width and stroke-width ratios[4] for print forms used on television. Four sizes of lettering were used, 24, 36, 48 and 60 point. The simple geometric forms were constructed by using I's and O's in combination or separate; the fully rounded letter O of Futura Medium doubled as a geometric circle.

The 30 sets of symbols were printed on 3-inch by 5-inch transparent cards cut from 10 x 10-inch sheets of standard heavyweight overhead transparency sheets. The use of a transparent base simplified inverting alphanumerics and facilitated changing contrast backgrounds during the visual presentations. Reflection was controlled. (See Appendix A.)

As background to the black figures, three contrasting colors were used, white, gray, and dark gray, corresponding to values 1, 4 and 7 of the television gray scale. These backgrounds took for form of 4-inch by 6-inch pieces of posterboard. The two gray backgrounds were developed by mixing black and white poster paints[5] to create a series of shaded cards approximating values 4 and 7. The exact shades were validated by measuring their reflectance value against a Conrac EIA Logarithmic Chart (gray scale) by use of a Tetronia 726 oscilloscope (set at .686 video level, reflection 20/1 contrast ratio) and a PC-70 Norelco I.

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[4]See "Description of Experimental Conditions," pp. 67-8, for recommended ratios.

[5]Prang Tempera Color 832 White and Prang Tempera Color 834 Black.

O. camera. The background cards were displayed on camera under 225 foot candles of spotlight. The appropriate cards were selected when their shades registered equal to the desired values.

Equipment and Facilities

The controlled-scan video signal was transmitted live on-air via the sub-carrier channel of WFBE-FM after having been compressed (encoded via Colorado Video, Inc., Video Converter 201A) to FM bandwidth. The signal was expanded at the receiving end by the decoding video converter (Colorado Video, Inc., 220-A Video Converter). Only the video capacity of the sub-carrier channel was used; the audio was not.

The vidicon camera (Sony Video Camera, CVC-2100A, AC117 V60c/s, 12W Max.) was mounted overhead to facilitate the operator's changing cards. Two photocopy lights located one on either side of the camera and each 22 inches from the display surface at angles of 45 degrees to the surface supplied 118 foot-candles of illumination as measured by the Weston Photronic Foot-Candle meter, model 614. The display surface was a 19 x 25-inch EIA Logarithmic Chart which served to offset any compensating contrast adjustment by the automatic video level-setting mechanism of the camera. The lens (telewide 20, zoom f=20-80 mm 1:25 No. 176063) was focused manually to maximize image clarity. Its focal settings for size were determined by measuring the height of the symbol image (1/4, 3/8, 1/2 or 5/8-inches) on the receiving set in the classroom. The f-stop set at 5.6 provided maximum distinction among shades of the gray scale on the Logarithmic Chart.

For presentation, the stimulus materials were positioned in the center of the logarithmic chart.

At the receiving end of the controlled-scan signal, a 23-inch television set was used to display the stimuli. The width of the screen was 20.25 inches. The receiver was positioned on a standard elevated stand (54 inches high) at a forward tilt of eight degrees.

The classroom setting was one-half of a double room divided by folding doors. Six classroom desks and chairs were arranged in a 90 degree arc 10.5 feet from the screen. Viewer distance was six and one quarter widths of the screen, the distance judged optimal for TV viewing:

> There is only one truly optimum viewing distance in the audience volume. Studies show that the eye moves in well-dispersed patterns of fixation when watching a visual display that subtends a visual angle of 9°, i.e., is located at a distance of 6¼ times the image width. At this distance, the eye takes in the whole display, rather than concentrating on a particular section.[6]

Each desk was angled to face toward the television screen. The desks were placed so that the distance of the viewer's eyes would most closely approximate 10.5 feet

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[6] G. F. McVey, "Where Do We Sit?" Educ. TV., I, No. 14 (1969), 25.

without immobilizing the viewer's head. Viewing angles were nine degrees, 27 degrees and 45 degrees off axis on either side of a line drawn perpendicular to the face of the screen. The desks and chairs were positioned so that the angles bisected them. A master plan of the seating arrangement was drawn on the floor with masking tape and desk positions were checked before each treatment.

treatment.

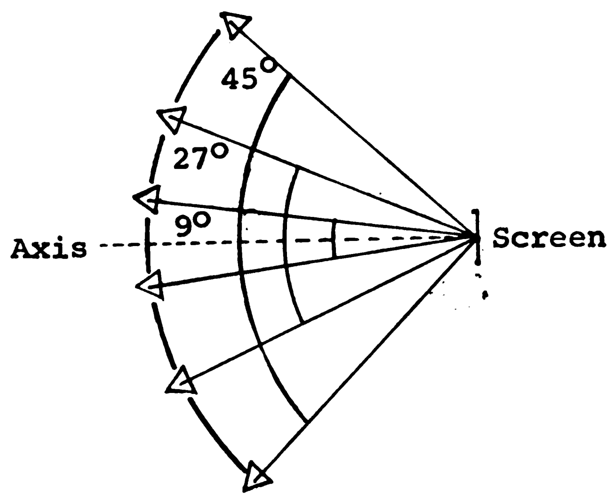

Figure 3-1.--Diagram of Optimal Seating Arrangement.

Glare on the screen was controlled by covering all windows with black paper and tilting the television receiver forward. The flourescent ceiling lights, which were recessed in inverted V-shaped coves, ran parallel to the screen surface and posed no problem. Only that bank of lights over the students' writing surfaces was used. Ambient illumination at the desk tops measured 40 foot-candles for those students at the nine degree angles, 29 foot-candles at the 27 degree angles, and 16 foot-candles at the 45 degree angles. The different readings were the result of the single recessed bank of lights overhead running in a straight line while the subjects were seated in a semi-arc. For purposes of this study foot-candles were perfectly confounded with viewing angle. (Note: for note-taking while viewing television, Educational Facilities Laboratories[6] recommends approximately 30 foot-candles of ambient illumination, while the Chief Engineer of Instructional Television for Michigan State University, F. Henderson, recommends 20 foot-candles. The legend accompanying the Weston Photronic Foot-Candle Meter indicates that 10-20 foot-candles are required for reading usual print, while 20-50 foot-candles are necessary for reading fine print.) Ambient illumination at the screen measured five foot-candles.

Description of Experimental Conditions:

Symbol brightness:

1 foot-candle (.32 foot-lamberts)
Black characters correspond to #10 on the gray scale.

Background brightnesses:

White--34 foot-candles (10.82 foot-lamberts), #1 on gray scale.
Gray--17 foot-candles (5.41 foot-lamberts), #4 on gray scale.

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[6]Dave Chapman and Frank Carioti, "Seeing, Hearing and Learning," Design for ETV, Planning for Schools with Television (New York: Educ. Fac. Labs., 1968) p. 44.

Dark gray--2 foot-candles (.64 foot-lamberts), #7 on gray scale.

When converted to Nominal Reflectance readings of the EIA Logarithmic Gray Scale, value #1 corresponds to 80 per cent nominal reflectance, value #4 corresponds to 28 per cent, value #7 to 9.2 per cent, and value #10 to 3 per cent. Approximate contrast ratios calculated in reflectance terms were: high contrast--27:1, medium--9:1, and low--3:1.

Symbol-background relationships and brightness contrasts:

High contrast black-on-white, 10:1 on gray scale.
Medium contrast black-on-gray, 10:4.
Low contrast black-on-dark-gray, 10:7.

Symbol style:

Futura Medium, upper case.
Chartpak Velvet Touch Lettering sheets, 24 pt./M3024 CL, 36 pt./M3036 CL, 48 pt./M3048 CL, 60 pt./M3060 CL.

Symbol width:

77 per cent of symbol size. (Recommended width-to-height ratios are 2:3 to 6:7.)

Stroke Width:

Medium, 17 per cent of symbol height. (Recommended stroke ratio is 1/5 of symbol height.)

Symbol size:

Measured in inches at screen surface;	in type point;	in visual angle.
1/4 inch	24 point	7 minutes
3/8	36	10
1/2	48	14
5/8	60	17

Horizontal spacing:

At least 1/4 inch between characters.

Number of symbols:

70, alphanumerics, inverted alphanumerics, and simple geometric forms.

Number of subjects:

72, ages 10-13.

Visual characteristics of subjects:

Screened for 20/20 normal acuity or corrected vision.

Viewing distance:

6¼ screen widths or 10.5 feet.

Viewing angles:

9 degrees off axis from a line drawn perpendicular to screen.
27 degrees
45 degrees

Monitor size:

23-inch RCA, model JR 968W, 1973. Screen width was 20.25 inches.

System resolution:

TV lines resolved 300. (Maximum resolution capability of broadcast television is 525 lines.)

System signal-to-noise ratio:

Picture signal-to-noise 34 dB. (Typical broadcast color/monochrome camera specifications produce a signal-to-noise ratio of 46 to 48 dB, while 2-inch videotape produces a ratio of 48-50 dB, according to specifications of Gates Division, Harris-Intertype Corporation, 123 Hampshire Street, Quincy, Illinois.)

Instrument

The measure of legibility was the score achieved by subjects in identifying the sets of characters displayed on the controlled-scan television screen. Subjects were required to copy the displayed characters onto a response sheet with numbered blank spaces (1 to 30). (See Appendix B.)

In scoring the responses, each character copied in correct form and order was awarded a value of 1; symbols omitted or copied incorrectly were scored 0. Within each contrast condition the highest score possible was 44, a total of 132 for all three conditions.

Procedure

Transmission of the stimulus materials required two operators, the first to change the display cards and the second to time the changes and manually switch the video converter. The visuals were changed ever 15 seconds allowing viewers ten seconds of exposure to the displayed characters. Because of the relative slowness of the scan (seven seconds), the first character of each set did not appear until two-three seconds after the scan began. That coupled with the momentary blackout between frames influenced viewing time per set by the subjects. The first operator had approximately five seconds to change display cards.

In displaying the visuals, the desired background card (white, gray, or dark gray) was centered on the logarithmic chart; then the transparent cards of characters were placed in sequence on the background cards. After displaying ten consecutive sets of characters, the background card was changed. This process was repeated after 20 sets until the total number (30) was displayed.

Each size of characters was presented to three separate groups of subjects with the order of contrast alternated for each presentation. The schedule of presentation was as follows:

Presentation and Group Numbers	Size	Contrast Order			Broadcast Time
1	1/4"	1	2	3	9:20 a.m.
2		2	3	1	9:40 a.m.
3		3	1	2	10:00 a.m.
4	3/8"	1	2	3	10:20 a.m.
5		2	3	1	10:40 a.m.
6		3	1	2	11:00 a.m.
7	1/2"	1	2	3	11:20 a.m.
8		2	3	1	1:10 p.m.
9		3	1	2	1:30 p.m.
10	5/8"	1	2	3	1:50 p.m.
11		2	3	1	2:10 p.m.
12		3	1	2	2:30 p.m.

Each presentation was overseen by the experimenter who seated the subjects, checked the positions of desks in relation to the television receiver, and delivered instructions to the subjects. (See Appendix C.) Transmission of the stimuli was scheduled at 20 minute intervals. Actual treatment time was seven and one half minutes which allowed twelve and a half minutes for subject movement and instruction. The subjects were given minimal practice prior to stimulus display. During the course of the treatment the experimenter announced the number of the upcoming frame or set of characters.

The procedure, instrument, and statistical design were pilot tested a month prior to the actual experiment. The pilot was used primarily as a formative check on the experimental system to suggest changes to improve the system. There were sufficient differences between the pilot test and the actual experiment to question a detailed comparison of results. For example, (1) the pilot instrument was presented via videotape recording as compared to live on-air broadcast of the actual experiment, (2) only 24 subjects were tested in the pilot study as compared to 72 in the actual, (3) the pilot instrument was shorter in length (24 sets of characters) compared to the actual instrument (30 sets of characters), (4) the symbol style was changed from Gothic Bold to Futura Medium to conform more closely with recognized height-to-width and stroke-width ratios, and (5) the stimulus materials for the actual experiment were modified to improve their random order. In comparing results, however, those main effects and interaction found significant by the actual experiment were also found significant by the pilot test.

Research Hypotheses

The following hypotheses were generated to explore the relationships of the main effects and their interactions to legibility. The research hypotheses were:

> Hypothesis 1. There will be differences among the mean legibility scores of subjects who identify sets of symbols displayed on controlled-scan television at visual angles (sizes) of 7, 10, 14, and 17 minutes of arc. It is predicted that as size increases legibility scores will increase.
>
> Hypothesis 2. There will be differences among the mean legibility scores of subjects who identify sets of symbols displayed on controlled-scan television at contrast conditions of black on white (high contrast), black on gray (medium), and black on dark gray (low contrast). It is predicted that as contrast decreases legibility scores will decrease.
>
> Hypothesis 3. There will be differences among the mean legibility scores of subjects who identify sets of symbols displayed on controlled-scan television when viewed from angles of 9, 27 and 45 degrees off-axis. It is predicted that as viewing angles increase legibility scores will decrease.
>
> Hypothesis 4. There will be interaction among the main effects size, contrast, and viewing angle.

Design and Analysis

The main effects and their interactions were analyzed by a three-way analysis of variance with repeated measures. Twelve different treatment groups (four sizes of display symbols by three viewing angles) with three sets of repeated measures (the three contrast conditions) created 36 cells in the design. Each of the twelve treatment groups contained six subjects. (See Figure 3-2.)

Size	Angle	Replication	Repeated Measures: Contrast 1	Contrast 2	Contrast 3	
SIZE 1	A1	R 1 ⋮ R 6				n:6
	A2	R 7 ⋮ R12				n:6
	A3	R13 ⋮ R18				n:6
SIZE 2	A1	R19 ⋮ R24				n:6
	A2	R25 ⋮ R30				n:6
	A3	R31 ⋮ R36				n:6
SIZE 3	A1	R37 ⋮ R42				n:6
	A2	R43 ⋮ R48				n:6
	A3	R49 ⋮ R54				n:6
SIZE 4	A1	R55 ⋮ R60				n:6
	A2	R61 ⋮ R66				n:6
	A3	R67 ⋮ R72				n:6

N=72

Figure 3-2.--Design of the Study.
Three-way Analysis of Variance with Repeated Measures.

An estimate of the strength of association (Kirk)[6] was calculated for those effects.

The Scheffé[7] method of multiple comparisons was applied <u>post hoc</u> to those sources of variation in which significant differences occurred. Simple contrasts of mean differences were tabulated for the main effects. Interaction effects were graphed. The purpose of the multiple comparisons technique was to determine those groups contributing to each source of variation found significant.

The reliability of the test instrument was estimated for each size by contrast condition using as data the number of correct responses to each item and the score for each subject (Hoyt).[8]

In addition, an item analysis was undertaken to compare the accuracy of identification of the three types of characters displayed--alphanumerics, inverted alphanumerics, and geometric forms. The comparisons were calculated as percentages.

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[6] Roger Kirk, <u>Experimental Design: Procedures for the Behavioral Sciences</u> (Belmont, Cal.: Brooks/Cole Pub.), p. 198.

[7] Gene Glass and Julian Stanley, <u>Statistical Methods in Education and Psychology</u> (Englewood Cliffs, N.J.: Prentice-Hall, Inc.), pp. 381-95.

[8] Cyril Hoyt, "Test Reliability Estimated by Analysis of Variance," <u>Psychometrika</u>, VI, No. 3 (1941), 153-60.

Summary

Seventy-two upper elementary school students with normal or corrected vision were randomly assigned to 12 treatment groups of six subjects each to view and copy 30 sets of black printed characters (5, 4 or 3 symbols per set) transmitted via controlled-scan television to a classroom. Four sizes of characters (1/4, 3/8, 1/2 and 5/8-inch as measured at the viewing screen) were displayed against three separate backgrounds (white, gray, dark gray) and viewed from three different angles, 9, 27 and 45 degrees on either side of a line drawn perpendicular to the viewing screen. Each group viewed only one size but all three contrast conditions. Subjects sat in an arc six and one quarter widths of the screen from the TV set.

During presentation subjects were exposed 10 seconds to each display set with instructions to copy what they saw. Minimal practice preceded testing. The measure of legibility of the displayed characters was the number of correct responses by the subjects.

A description of the experimental conditions was recorded in detail.

The statistical design of the study was a 36-cell matrix created by the 12 treatment groups (four sizes of display symbols by three viewing angles) with three sets of repeated measures (the three contrast conditions). Four

hypotheses were postulated to test the main effects and their interactions at the .05 alpha level.

Statistical analysis was by a three-way analysis of variance with repeated measures. The Scheffé method of multiple comparisons was applied <u>post hoc</u> to those sources of variation in which significant differences were found, and an estimate of the strength of association was calculated. The reliability of the test instrument was estimated and a descriptive item analysis was undertaken to compare the accuracy of identification of the three types of characters displayed.

CHAPTER IV

ANALYSIS OF DATA

Univariate analysis of variance was used to test the hypotheses about the main effects and their interactions. All hypotheses were tested at the .05 alpha level with the appropriate degrees of freedom. The results are summarized in Table 4-1.

The first hypothesis stated in null form was:

> Null Hypothesis 1. There will be no differences among the mean legibility scores of subjects who identify sets of symbols displayed on controlled-scan television at visual angles (sizes) of 7, 10, 14 and 17 minutes of arc.

Analysis of variance resulted in an F-value of 66.54 which was significant at the .001 level. The null hypothesis was rejected.

The second hypothesis stated in null form was:

> Null Hypothesis 2. There will be no differences among the mean legibility scores of subjects who identify sets of symbols displayed on controlled-scan television at contrast ratios of black-on-white (high contrast), black-on-gray (medium), and black-on-dark gray (low contrast).

Analysis of variance produced an F-value of 463.33 which was significant at the .001 level. The null hypothesis was rejected.

TABLE 4-1.--Summary of the Analysis of Variance of Data on Legibility

Source of Variation	df	Sum of Squares	Mean Squares	F	"p"
BETWEEN SUBJECTS	71	17177.96			
Size (S)	3	12984.16	4318.05	66.54	<.001
Viewing Angle (A)	2	191.86	95.93	1.47	>.05
(SxA)	6	99.21	16.54	0.25	>.05
(R:SA)*	60	3902.72	65.05		
WITHIN SUBJECTS	144	21064.00			
Contrast (C)	2	17015.25	8507.63	463.33	<.001
(SxC)	6	1676.05	279.34	15.21	<.001
(AxC)	4	50.31	12.58	0.69	>.05
(SxAxC)	12	118.95	9.91	0.54	>.05
(RxC:SA)**	120	2203.44	18.36		
TOTAL	215	38241.96			

*R denotes replication. This is the error term for Between Subjects sources of variation.

**R denotes replication. This is the error term for Within Subjects sources of variation.

The third hypothesis in null form was:

> Null Hypothesis 3. There will be no differences among the mean legibility scores of subjects who identify sets of symbols displayed on controlled-scan television when viewed from angles of 9, 27 and 45 degrees off axis.

Analysis of variance produced an F-value of .15 which was not significant at the .05 level. The null hypothesis was not rejected.

The fourth hypothesis stated in null form was:

Null Hypothesis 4. There will be no interactions among main effects size, contrast and viewing angle.

Analysis of variance of two-way interactions resulted in F-values of 0.25 for the size by angle interaction, 15.21 for the size by contrast interaction, and 0.69 for the angle by contrast interaction. Of these, only the size by contrast interaction was significant at the .001 level. Therefore, the null hypothesis for size by contrast was rejected, while the null hypotheses for size by angle and angle by contrast were not rejected. Analysis of variance of the three-way interaction size by angle by contrast resulted in an F-value of .54 which was not significant at the .05 level. The null hypothesis was not rejected.

A summary of mean scores on legibility of significant sources of variation is presented in Table 4-2.

TABLE 4-2.--Mean Scores* on Legibility of Size(S), Contrast (C), and SxC.

	Contrast 1 (high)	Contrast 2 (medium)	Contrast 3 (low)	
Size 1 (small)	S1xC1 8.78	S1xC2 9.89	S1xC3 .11	S1= 6.26
Size 2	S2xC1 18.44	S2xC2 20.56	S2xC3 .33	S2=13.11
Size 3	S3xC1 29.11	S3xC2 28.82	S3xC3 4.39	S3=20.78
Size 4 (large)	S4xC1 33.94	S4xC2 34.50	S4xC3 11.94	S4=26.80
	C1 = 22.57	C2 = 23.44	C3 = 4.19	

*Maximum score possible = 44.

The strength of association of those effects and interactions found significant was estimated (Kirk).[1]

[1] Kirk, op. cit., p. 198.

$$\hat{\omega}^2_{1^*|s} = \frac{SS_{size} - 3\left(MS_{R:SA}\right)}{SS_{total} + MS_{R:SA}} = 0.3339$$

$$\hat{\omega}^2_{1|s} = \frac{SS_{contrast} - 2\left(MS_{RC:SA}\right)}{SS_{total} + MS_{RC:SA}} = 0.4438$$

$$\hat{\omega}^2_{1|sc} = \frac{SS_{sc} - 6\left(MS_{RC:SA}\right)}{SS_{total} + MS_{RC:SA}} = 0.0410$$

*Denotes the dependent variable legibility.

According to the above calculations, the independent variable size accounted for 33.39 per cent of the total variance in the dependent variable legibility, while the independent variable contrast accounted for 44.38 per cent. The interaction between size and contrast accounted for an additional 4.1 per cent.

The *post hoc* Scheffé method of multiple comparisons revealed the following results when applied to those main effects found significant (size and contrast) by analysis of variance. (See Tables 4-3 and 4-4.)

TABLE 4-3.--Mean Differences between Sizes (S).

SIZE	1 (1/4")	2 (3/8")	3 (1/2")	4 (5/8")
2	(S2-S1) 6.85*			
3	(S3-S1) 14.52*	(S3-S2) 7.67*		
4	(S4-S1) 20.54*	(S4-S2) 13.69*	(S4-S3) 6.02*	

*Significant at the .05 level.

TABLE 4-4.--Mean Differences between Contracts (C).

CONTRAST	1 (high)	2 (medium)	3 (low)
2	(C2-C1) .88		
3	(C3-C1) -18.38*	(C3-C2) -19.25*	

*Significant at the .05 level.

The interaction effect between size and contrast was graphed. (See Figure 4-1.)

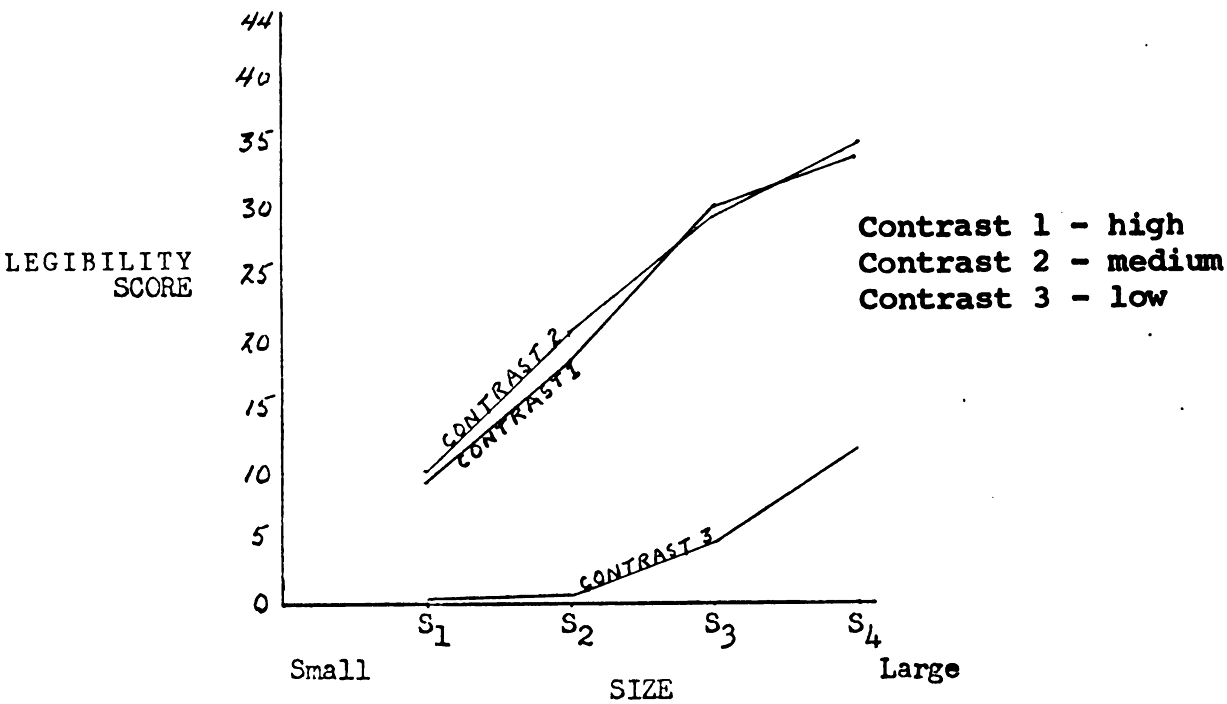

Figure 4-1.--Interaction effect between Size of Symbols and Contrast Conditions.

The Scheffé method of multiple comparisons was used to examine the interactions between the two independent variables size and contrast. In effect, the Scheffé analysis represented an attempt to determine if the contrast curves as illustrated by the graph (see Figure 4-1) were parallel over all sizes. Significant interactions were found in four combinations, all involving contrast three. There was no significant interaction between contrast one and contrast two across any size. The most obvious difference was not between contrast one and contrast two, but between contrasts one and two versus contrast three (low).

The reliability of the test instrument was established for each size by contrast condition using as data the number of correct responses to each item and the score for each subject on each contrast (Hoyt).[2] The results are summarized in Table 4-5.

TABLE 4-5.--Hoyt's Coefficient of Reliability for Internal Consistency of the Test Instrument within Each Size and Contrast.

Size	Contrast	Reliability Coefficient
1 (1/4")	1 (high)	.88
	2 (medium)	.84
	3 (low)	*
2 (3/8")	1	.84
	2	.84
	3	**
3 (1/2")	1	.87
	2	.86
	3	.88
4 (5/8")	1	.79
	2	.78
	3	.88

*Only 2 out of 132 were identified accurately.

**Only 4 out of 132 were identified accurately.

An item analysis was undertaken to compare the accuracy of identification of the three types of characters displayed--alphanumerics inverted alphanumerics, and geometric forms. Of the 132 characters displayed, 67 were

[2]Hoyt, op. cit., pp. 153-60.

regular alphanumerics, 46 were inverted alphanumerics, and 19 were simple geometric forms. The item analysis was descriptive in nature with percentages of accuracy within all sizes and contrasts forming the basis of comparison. The results are presented in Table 4-5.

TABLE 4-6.--Percentage of Accuracy of Identification of Types of Characters for all Three Contrast Conditions within all Four Sizes.

Size	Contrast	Regular Alphanumerics	Inverted Alphanumerics	Geometric Forms
1 (1/4")	1 (high)	34.07%	5.43%	1.75%
	2 (med.)	38.31	5.80	7.02
	3 (low)	0.50	0.00	0.00
2 (3/8")	1	62.19%	23.55%	23.68%
	2	67.16	29.35	22.80
	3	0.50	0.72	0.00
3 (1/2")	1	86.07%	36.96%	45.61%
	2	86.32	44.20	43.86
	3	19.40	1.81	0.00
4 (5/8")	1	89.55	63.04	68.42
	2	90.04	65.58	68.42
	3	39.55	13.77	15.79

Summary

Four hypotheses were postulated to test the main effects (size, i.e., visual angle, contrast, viewing angle) and their interactions at the .05 alpha level. Univariate analysis of variance with repeated measures indicated significant relationships between the dependent variable legibility and three sources of variation: (1) size,

(2) contrast, and (3) the interaction between size and contrast. An estimate of the strength of association of those main effects and interactions found significant suggested that size accounted for 33.39 per cent of the total variance in legibility, while contrast accounted for 44.38 per cent and the interaction effect 4.1 per cent. When the Scheffé method of multiple comparisons was applied to the significant sources of variation, significant differences were shown between all combinations of sizes and between all contrasts except one (high) and two (medium). When applied to interactions among levels of size and contrast, four combinations showed significance, all involving contrast three (low); no significant interactions were noted between contrast one and contrast two across all sizes. The application of Hoyt's estimate of reliability of the test instrument for each size by contrast condition (12 conditions) resulted in reliability coefficients in excess of .78 for each condition except contrast three in the two smaller sizes where subject responses were too few to provide meaningful readings. A descriptive item comparison of the three types of characters displayed was reported in percentages of accuracy for all contrasts within each size. A discussion of the findings and their implications is found in Chapter V.

CHAPTER V

SUMMARY AND CONCLUSIONS

This was an exploratory study to develop guidelines for the selection and production of visualized instructional materials for use on controlled-scan television in a classroom setting. CSTV is a new video broadcast medium offering advantages of reduced cost and bandwidth but is limited to displaying still pictures at a relatively slow frame rate (seven seconds for this study) with a subsequent loss of resolution. Development of the guidelines was based on data derived from an experimental determination of legibility standards for this new medium. It was theorized that display limitations could be compensated for graphically.

A large body of research literature on educational TV has proved that television can be used effectively for instructional purposes. In the broad area of visualized instruction current research is attempting to establish a theoretical base from which meaningful studies can develop. In particular, there is a concerted effort to define visual terms and develop taxonomies and hierarchies of functions and their applications to learning. Variables affecting learning from visuals, such as individual differences, use of cues, and pictorial forms are being studied, and results are being applied in a more systematic approach to the design and use of pictorials for instruction.

In the more specific area of legibility of televised displays, research is limited. Of three potential sources, (1) educational television, (2) commercial TV, and (3) information display systems, the latter is the most productive particularly as a result of military studies (Shurtleff). Two experimental studies in educational television stand out, Seibert et al and Neal, both of which recommend legibility standards for the design of visuals for use on regular TV. G. F. McVey summarizes experimental results in a comprehensive set of guidelines for TV users. No study exists on the legibility of CSTV.

The present study examined the relationships of three independent variables to legibility. The variables were: (1) visual angle (a function of symbol size and viewer distance), (2) brightness contrast (characters to background), and (3) viewing angle. Legibility was operationalized by 72 upper elementary school students viewing and identifying a total of 30 sets of characters (alphanumerics, inverted alphanumerics, and geometric forms) displayed on a TV receiver. Each subject, pre-screened for normal vision, was randomly assigned to one of 12 treatment cells to view ten sets of characters at each of three contrast conditions (high, medium, low) within one of four sizes (1/4, 3/8, 1/2 or 5/8-inch height at the screen). Within cells subjects were randomly assigned to viewing positions six and one quarter screen widths distance from the receiver at angles of nine degrees, 27 degrees, or 45 degrees to the right and left of a center line. Subjects were exposed to each set (five, four, or three-characters per set) for ten seconds with instructions to copy the characters displayed; there was a five-second lapse between sets. Total time per treatment was seven and one half minutes. The sets of visuals were transmitted on-air via a sub-carrier channel of an FM radio station for each of the 12 treatments.

The statistical design of the study was a 36-cell matrix created by the 12 treatment groups (four sizes of display symbols by three viewing angles) with three sets of repeated measures (the three contrast conditions). Four hypotheses were postulated to test the main effects and their interactions at the .05 level.

Univariate analysis of variance with repeated measures indicated significant relationships between the dependent variable legibility and three sources of variations: (1) size, (2) contrast, and (3) the interaction between size and contrast. When the Scheffé method of multiple comparisons was applied to the significant sources of variation, significant differences were shown between all sizes; however, no difference was found between high and medium contrast conditions. Those interactions found significant among levels of size and contrast all involved the low contrast condition; no significant interactions were noted between the high and medium contrast conditions across all sizes. A reliability check of the test instrument for each size by contrast condition resulted in reliability coefficients in excess of .78 for each condition except two where responses were too few to be meaningful. A descriptive item comparison of the three types of characters was reported in percentages of accuracy for all contrasts within each size.

Conclusions

Analysis of variance (Table 4-1) indicated that two of the three main variables had significant effects on legibility and that one two-way interaction was significant, all at the .05 alpha level.

Conclusion 1. As predicted, significant differences were found between legibility scores of subjects viewing each of the symbol sizes. The mean differences between sizes (Table 4-3) showed a relatively uniform increase in scores as symbol sizes progressed from small to large.

To be legible to upper elementary school students with normal vision, characters displayed on controlled-scan television should subtend a vertical visual angle of at least 17 minutes of arc (5/8-inch vertical size at the screen when viewed from a distance of 10.5 feet).

Conclusion 2. Significant difference was found between legibility scores of subjects viewing contrast three (low contrast) and contrast one (high contrast), and between contrast three and contrast two (medium contrast). However, there was no difference between legibility scores of subjects viewing contrast one and contrast two. The high contrast (figure-to-background ratio of 10:1 in terms of the gray scale) and medium contrast (10:4) display conditions resulted in equivalently superior legibility scores by subjects viewing controlled-scan television. The low contrast condition yielded comparatively inferior scores.

To be legible to upper elementary school students with normal vision, a high or medium contrast ratio (representing no fewer than six shade separations on the television ten-step gray scale) of characters-to-background should be used on controlled-scan television. Low contrast conditions with as few as three shade separations should be avoided where discrimination is required.

Conclusion 3. No difference was found between legibility scores of subjects viewing displays from six and one quarter screen widths (10.5 feet) at angles of nine degrees, 27 degrees, or 45 degrees to the left or right of a line drawn perpendicular to the screen.

Upper elementary school students with normal vision should identify symbols displayed on controlled-scan television with equal accuracy when viewing occurs within a 90 degree arc in front of the receiver. Desks should be positioned to face the screen.

Conclusion 4. There was no three-way interaction among the independent variables (size by contrast by viewing angle) nor were there two-way interactions between size by angle or angle by contrast. There was significant two-way interaction between size by contrast with the most obvious difference occurring not between contrast one and two but between a combination of contrasts one and two versus contrast three (Figure 4-1). Significance within the size by contrast interaction occurred only when the low contrast condition was involved: characters displayed at all sizes were equally legible at contrasts one and two, but not at contrast three; characters displayed under contrast conditions one and two were equally legible at sizes one, two, three and four, but not under contrast condition three.

To be legible to upper elementary school students with normal vision, low contrast conditions on controlled-scan television displays should be avoided regardless of sizes of characters involved.

The estimate of the strength of association of those effects and interaction found significant accounted for a substantially high proportion (81.87 per cent) of the total variance in legibility. Visual angle, contrast, and their interaction are essential variables in determining legibility standards for viewing of controlled-scan television.

The estimate of reliability of the test instrument yielded relatively high positive coefficients within each size and contrast with the exception of two conditions where subject responses were too few to provide meaningful measures. The reliability coefficients indicated high internal consistency of the test instrument.

The descriptive item analysis to compare the accuracy of identification among the three types of characters showed differences between regular alphanumerics and the other two types, inverted alphanumerics and geometric forms. Regular alphanumerics were appreciably more identified than the other two types within each size and contrast as indicated by percentages of accuracy of items. There was considerably less difference between inverted alphanumerics and geometric forms.

It would appear that the degree of familiarity with the displayed characters influenced the subjects' ease of identifying them. Those characters which were familiar (regular alphanumerics) to the upper elementary school student were more readily identified than those which were not familiar (inverted alphanumerics and geometric forms). E.G., identification of regular alphanumerics at size four, contrasts one and/or two, resulted in an accuracy level of approximately 90 per cent as compared to scores ranging from 63 per cent to 68 per cent for the other two types. However, in the two unfamiliar types as in the familiar, there were noticeable percentage gains within each contrast as size of characters increased. It is concluded that characters which are unfamiliar to viewers should be treated differently from those which are familiar by making the unfamiliar characters larger.

Discussion of Results

The minimum visual angle recommended by this study for characters displayed on controlled-scan television (17 minutes of arc) is larger than those visual angles recommended by Seibert _et al_ (ten minutes) and Neal (eight minutes) for closed-circuit television. The difference in size supports the thesis that controlled-scan television is a unique medium requiring its own graphic production consistent with its capabilities. In other words, the reduced resolution of CSTV affects legibility standards.

In determining standards for size of characters other factors should be considered, some of which suggest larger symbols, some smaller. The possibility that there are often students with impaired vision (20 out of 94 possible subjects for this study were rejected as being below normal vision) suggests that sizes should be increased. Also, when the full television screen is used for display of characters (not just the center as for this study), then it is suggested that larger sizes should be used to compensate for the decline of resolution at the edges of the screen. (Shurtleff recommends increasing size by 11 per cent.) By contrast, a consideration supporting reduced size is that characters in meaningful combinations are more readily identifiable than individual characters; that is, letters formed into words are easier to read than combinations of unrelated letters.[1]

When selecting or designing visual materials for use on CSTV, users should be guided by the desirability of relatively high contrast conditions where discrimination is essential. If existing materials do not meet legibility standards when displayed on CSTV, they should be discarded or re-designed. If superimposition is used as a technique for displaying characters, then the nature of the background will dictate the direction of contrast. While lack of contrast may be compensated for, in part, by increasing the size of characters, it is no guarantee that legibility will

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[1]Shurtleff, "Part II," Design Problems, p. 48.

be adequate, particularly in the darker range of the gray scale where shades tend to converge. The use of colored visuals on black-and-white CSTV will require use of a conversion chart to ensure adequate contrast.

The necessity of high contrast conditions should be enhanced by the designers and users of visual materials. Teachers should think in terms of visuals which highlight pertinent learning cues; artists should emphasize contrast through composition, style and shading; and engineers should peak equipment to maximize contrast. Because of the desirability of relatively high contrast display, CSTV lends itself to the pictorial form of simplified line drawings that Dwyer found so effective in fixed-time presentations of visualized lessons.

Concerning the findings on brightness contrast, it had been expected that there would have been difference between the high contrast condition and the medium contrast condition due to the effect of irradiation; there was a visually perceptible narrowing of stroke width within the high contrast condition (black characters on a white background). However, there was no evidence of the effect of irradiation on legibility which it was suspected would have manifested itself in lower accuracy of identification. A more legitimate test of the influence of irradiation would have been to reverse polarity of the stimulus sets (white characters on a black background) to create a contrasting condition.

From past research on the influence of irradiation under high contrast conditions, the following basic guideline is suggested: to compensate graphically for irradiation, use bolder stroke widths for black-on-white displays and narrower stroke widths for white-on-black displays. Irradiation also influences spacing between letters and words, particularly in the white-on-black condition where letters too close together tend to fuse.

The results on viewing angle support Shurtleff, McVey, Educational Facilities Laboratories, and television manufacturers (e.g., RCA) who recommend that for viewers located within an area up to 45 degrees off axis a television display should be equally legible. However, the results are more liberal than those of both Seibert et al and Neal; Seibert found significant legibility loss between angles of 19 and 38 degrees while Neal recommended a "viewing cone" 30 degrees on either side of a center line.

In addition to horizontal viewing angle, other viewing conditions such as minimum-maximum viewing distances and vertical viewing angles should be considered by users of controlled-scan television who may gain direction from regular TV sources, particularly Educational Facilities Laboratories[2] and McVey.[3]

In this study viewing angle may have been influenced by ambient illumination. The fact that subjects at each angle viewed the visual stimuli from different illumination levels at their desks may have affected identification of displayed characters. For example, subjects at the widest viewing angle (45 degrees) were under the lowest illumination, a circumstance which may have increased legibility scores.

The estimated high proportion of the total variance in legibility accounted for by visual angle, brightness contrast and their interaction emphasizes the importance of these effects as major considerations in developing legibility guidelines. It also supports the necessity of determining visual thresholds for symbol size and contrast if legibility is basic to learning through the sense of sight.

The difference in scores of types of characters (alphanumerics, inverted alphanumerics, geometric forms) revealed by the descriptive analysis suggests an interesting learning effect. It appears that previous knowledge of regular letters and numbers transfers to identifying those

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[2]Chapman and Carioti, Design for ETV, pp. 31-40.

[3]McVey, "Television: Some Viewer-Display Considerations," pp. 277-90.

same alphanumerics when displayed on CSTV, thereby accounting for the difference in scores. The similarity of legibility scores between the two unfamiliar types, inverted alphanumerics and geometric forms, adds credibility to this contention. In other words, the degree of familiarity or scale of difficulty of an item reflects on its legibility under the conditions of this experiment. The fact that there were noticeable score gains in the two unfamiliar types within each contrast as symbol sizes increased supports the guideline that unfamiliar characters should be larger than familiar ones.

The 90 per cent average of scores for 5/8-inch characters displayed within contrasts one and two meets the criterion of legibility used by Neal. This supports the recommendation that a visual angle of 17 minutes of arc is an acceptable threshold level or minimum size for alphanumeric characters displayed on controlled-scan television.

This study represents a unique opportunity to explore presentation guidelines for a new medium before it is used for group instruction. The guidelines, based on an experimental study of legibility and presented in the form of recommendations, suggest graphic standards compatible with the inherent capabilities of controlled-scan television. They are an attempt to serve in the design and selection of visual materials so that the probability of students learning from displays on CSTV will be maximized.

Guidelines

The following are guidelines for the selection and production of visual materials for instructional use on controlled-scan television based on the conclusions of this study.

Visual Angle (Size)

Given the recommended visual angle of 17 minutes of arc and viewing distance, the character size can be calculated mathematically.[4] A list of symbol sizes required for CSTV from various viewing distances may be found in Table 5-1.

The obviously critical viewing distance in a group situation is that which is farthest from the screen. Using as an example the recommended maximum viewing distance of 12 widths for group viewing of regular television, a viewer of CSTV on a 23-inch screen from a distance of 20.25 feet would require a character size of 1.2 inches. If the width of the character and its adjacent space is also 1.2 inches, and if the space between lines of printed material is three-quarters of the character height, then it would be possible to display eight lines of 17 characters.

Once the symbol size has been determined, it is relatively simple to translate it into art work. McVey[5]

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[4]S. Howard Bartley, Principles of Perception (Evanston, Ill.: Harper and Row), pp. 52-54.

[5]McVey, "Legibility," p. 19.

TABLE 5-1.--Symbol Sizes for CSTV from Varied Distances Based on a Visual Angle of 17 Minutes of Arc.

Viewing Distance from Screen in Feet	in Inches	Size of Symbol as Measured at the Screen in Inches.
4	48	.24
5	60	.30
6	72	.36
7	84	.42
8	96	.48
9	108	.54
10	120	.60
11	132	.66
12	144	.72
13	156	.78
14	168	.84
15	180	.90
16	192	.96
17	204	1.02
18	216	1.08
19	228	1.14
20	240	1.20
21	252	1.26
22	264	1.32
23	276	1.38
24	288	1.44

(Note: distance from screen is characteristically measured in screen widths, e.g., 4W is regarded as minimum viewing distance, 12-14W maximum. To determine symbol size when viewing distance is indicated in this manner, change screen widths to feet and/or inches and match the results to Table 5-1.)

advises the artist to divide the width of the art layout by the width of the television set on which it is to be displayed, then multiply the TV screen symbol size by that number. The result is the size of characters to be used by the artist corresponding to the desired display size on CSTV. For example, if the desired display size is 1.2 inches at the screen, the width of the art work is ten inches, and the width of the 23-inch television screen is 20.25 inches, then:

$$\frac{10}{20.25} = .49 \times 1.2 = .59 \text{ inches.}$$

The artist will need to work with characters approximately .6 inches in height.

Brightness Contrast

In designing pictorials for CSTV, it is recommended that adjacent shades be separated by at least three values of the gray scale and preferably more. Separation of six shades will ensure adequate legibility.

Viewing Angle

Students who view CSTV in a classroom group setting should sit within an area up to 45 degrees to the left or right of a line drawn perpendicular to the television screen. Within this conical area each student should be able to view the televised displays legibly.

Implications for Future Research

This study of the use of controlled-scan television for instructional purposes suggests further research.

1. Further research should occur in the relationship of the transfer process to the design of visuals for learning. For example, based on the referent background of a student, will transfer be negative or positive in response to visual stimuli? Viewer's background, type of message, meaning of message, and type of stimulus are variables whose influences on learning bear further study in the context of visual mediation.

2. Further research should also occur in the relationship of characters-in-combination to legibility. For example, a study using words as stimuli instead of separate characters would test the influence of symbols in meaningful union as opposed to the near-nonsense connotation of symbols identified individually.

3. Whereas this study dealt primarily with digital signs, further exploration should occur in the category of iconic signs (pictorials). Research exploring the relationship of pictorial forms (realistic continuous tone, semi-realistic solid tones, abstract line drawings) to learning would extend guidelines for the design of visuals compatible with the inherent capabilities of controlled-scan television.

4. Further study should be directed toward the relationship of visual acuity to the design of visuals.

Because there will be students with impaired or restricted visual acuity in many group viewing situations, what compensatory measures should be exercised to maximize the probability of visual stimuli being legible?

5. Further research should be undertaken into the relationship of ambient illumination to legibility. It is recommended that a study be conducted that would disengage foot-candles of illumination from viewing angle. That is, all subjects regardless of viewing angle or distance, would have equal illumination at their viewing positions.

6. Still another study should investigate the relationship of legibility to other forms of controlled-scan television, particularly to other brands of equipment and at varied frame rates.

APPENDICES

APPENDIX A

STIMULUS CHARACTERS

STIMULUS CHARACTERS

Characters for the display sets included all of the upper case letters of the alphabet plus all of the numerals to 9 with the exception of 0 and 1. These two digits were not used because of their tendency to duplicate the letters O and I. In addition, 14 letters were inverted horizontally as if viewed from the side in a mirror (B,C,D,E,F,G,J,K,L, N,Q,R,S,Z) and five were inverted vertically as if viewed from above in a mirror (A,T,U,V,Y). Six numbers were inverted horizontally (2,3,4,5,6,7); none was inverted vertically. Those letters and numbers that were not inverted were either not invertable (H,I,O,X) or too easily confused with other symbols (W,M; P,6). Eleven simple geometric forms were used: four right-angle triangles with their hypotenuses facing in different directions (Northeast, Southeast, Northwest, Southwest), a diamond, a square, an equilateral triangle, and four circles with their diameters pointing in varying directions (North to South, East to West, Northwest to Southeast, and Northeast to Southwest). These characters totaled 70 in number.

The transfer of inverted letters was simplified by printing them on transparent cards, because both sides of the surface could be used. However, when the reverse side was used, the inverted figures displayed a different reflectance rating. Therefore, it was necessary to rebuild the character on the obverse side using the inverted symbol as a pattern.

At the time of presentation, glare from the transparent display cards was controlled by positioning the photocopy lights at 45-degree angles to the display surface, and by ensuring that all display cards were flat in nature, not buckled or warped. A cover of non-glare glass was tested as a control for reflection but it was found not to be necessary if the above conditions were met. The transparent display cards were stored in a flatly pressed state when not in use.

The total number of symbols was randomly ordered and then divided into sets of five, four or three characters according to a pre-determined randomized order. The display sets were composed as follows:

1.*
2.
3.
4.
5.
6.
7.
8.
9.
10.
11.
12.
13.
14.
15.
16.
17.
18.
19.
20.

* Set numbers were not included in the visuals.

APPENDIX B

SUBJECT RESPONSE SHEET

NAME: ____________________ GRADE: __________

AGE: __________ SEX: Boy______ Girl __________

SIZE: 1 2 3 4 ANGLE: 1 2 3 CONTRAST ORDER: ________

1. ____________	16. ____________
2. ____________	17. ____________
3. ____________	18. ____________
4. ____________	19. ____________
5. ____________	20. ____________
6. ____________	21. ____________
7. ____________	22. ____________
8. ____________	23. ____________
9. ____________	24. ____________
10. ____________	25. ____________
11. ____________	26. ____________
12. ____________	27. ____________
13. ____________	28. ____________
14. ____________	29. ____________
15. ____________	30. ____________

APPENDIX C

INSTRUCTIONS TO SUBJECTS

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This is a study of a new form of television called controlled-scan or slow-scan television that may be used for teaching in schools. Unlike regular television, controlled-scan can present only a still picture and it takes seven seconds to build a single frame. Also, the medium is limited to black-and-white, no color.

A series of visuals consisting of letters, numbers, and simple geometric figures will be presented in the middle of the screen; you will be asked to copy the characters that you see on the television screen onto the response sheet in front of you. There are a total of 30 visuals with changes between them occurring every 15 seconds. The characters that you have to copy will be on display for about ten seconds. The screen goes blank between visuals during which time the number of the next frame will be announced.

You are advised that some of the characters are inverted, or turned backwards or upsidedown. To help you understand the idea of inverted characters, do the following simple exercise: write down the first five letters of the alphabet in capitals on the blank reverse side of your answer sheet. Then invert those letters -- A upsidedown, B backwards, etc. Do the same thing for the first five numbers and I will check them with you.

Now, turn over your response sheet to the front side.

Your instructions are to copy on your response sheet the sets of characters that you see displayed in the center of the television set in the order in which they are presented. Copy exactly what you see or think you see (best estimate) in the same order as presented on the screen. Do the very best you can at all times!

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