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ABSTRACT

This paper reviews research on pictorial stimulus complexity in instructional materials, examining still iconic visuals in particular. Five phases are proposed to assist in the integration of this research for generating useful hypotheses: (1) establishment of methodological and conceptual criteria; (2) collection of relevant literature; (3) identification and classification of variables; (4) analysis of data; and (5) identification of hypotheses and needed research. Limitations, delimitations, and assumptions for this integration are briefly discussed. A 90-item list of references is attached. (CMV)

Title • AN INTEGRATION OF RESEARCH FINDINGS FROM INVESTIGATIONS OF PICTORIAL STIMULUS COMPLEXITY

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BACKGROUND

As an applied field of communication, educational technology has concerned itself with the practical utilization of communications technology in the instructional process. This focus has created a large body of media research studies with discouraging appraisals of the value of these media research efforts (Bracht, 1970; Cronbach & Snow, 1977; Dwyer, 1978; Fleming, 1970; Hawkridge, 1973; Heidt, 1977; Parkhurst, 1975). It has been suggested, as one solution to these difficulties, that the pertinent variables in media research be reconceptualized.

In 1965, Lumsdaine and May stated that educational media research was a field frequently defined in terms of presentation modes rather than on a more fundamental basis. Both Conway (1967) and Knowlton (1964) observed that media researchers have made no consistent distinction between the sensory modalities involved in communication and the coding systems incorporated in the message. Knowlton noted the regrettable mix of pictorial and verbal elements in audiovisual presentations and the lack of a carefully described unit of analysis, specifically the pictorial iconic sign. This description, he continued, was essential to the development of a science of audiovisual communication. In 1966, Norberg lamented that considerable audiovisual research dealt only with media presentations; iconic signs had rarely been an experimental variable. In 1978, Levie clearly specified that one area of media research emphasis should be the symbolic codes of pictorial media. Levie was referring to the iconic coding system which uses referent symbols (e.g., pictures) to communicate, as opposed to the digital coding system (e.g., words and numbers) which communicates by non-referent symbols (Littlejohn, 1978; Schramm, 1977).

Salomon (1974) argued that media need not be represented only in terms of presentation techniques or technology systems (e.g., television, computer-assisted instruction), but could also be represented as consisting of messages (subject-matter content) or symbolic systems. This last method of representation has received the least emphasis. In delineating the potential elements in a taxonomy of media attributes, Salomon described a tentative hierarchy of symbol systems (e.g., digital, iconic), coding elements (e.g., dimensionality, iconicity), secondary coding systems (e.g., editing, sequencing), and such additional features as complexity, redundancy, or ambiguity. In a review of Salomon's analysis, Schramm (1977) acknowledged the desirability of such a taxonomy, regretted that it was not close at hand, and admitted that media researchers have "only the foggiest of ideas about the area that Salomon is opening up" (p. 87).

Many of the conceptual difficulties in media research may be related to a decreasing link, described by Hill (1978), between communication theory and instructional media research. Mielke (1972) also has noted that "the current trends and emphases in instructional media research . . . have involved increased association with educational psychology and decreased association with general communication theory and research" (p. 358). Similarly, Allen (1971) concluded that the "broad field of communication research never became integrated with the mainstream of instructional media research, and to this day these related disciplines are taking different routes" (pp. 6-7).

Dance (1970) observed that the diverse fields involved in the study of communication have created considerable looseness in the definition of the concept of communication. Westley and MacLean (1974) found this looseness counter productive, noting that there exists a "jungle of unrelated concepts and systems of concepts . . . and a mass of undigested . . . sterile empirical data" (p. 336). Consequently, Mortensen (1972) considered the prospects unlikely for a synthesized communication theory. Despite this deficiency, many communication models possess certain essential commonalities which can be directly related to instructional media research. Deutschmann, Barrow, and McMillan (1961) considered the Shannon-Weaver (1949) model as directly applicable to the classroom. Berlo (1960), moreover, observed that a comparison of the process models generally indicated a great deal of similarity.

One basic area of agreement among the various descriptive and graphic models of the communication process lies in the recognition of the importance of codification and sign usage. Littlejohn (1978), for example, described coding as a fundamental concern in the study of communication and concluded that "essentially every theoretical approach to communication takes place through the use of signs" (p. 80). Salomon (1974) stated that one of the key steps in designing instructional media is the selection of a symbolic coding system which is "isomorphic . . . to the learner's symbolic mode of thinking" (p. 401). According to Conway (1967), the translation of information from one mode to another (coding) is a significant empirical problem. The conceptualization of media research variables in terms of codes and symbol systems, as suggested by Conway (1967), Knowlton (1964), Lumsdaine and May (1965), Norberg (1966), and Salomon (1974) would be consistent with the calls for increased association of media research with communication theory.

The conceptual difficulties and conflicting results in media research have had ramifications on the guidelines for the design of instructional materials. Levie (1973) concluded that "the lack of . . . well-defined variables in pictorial stimuli has . . . hindered progress in understanding what kinds of pictures may have what kinds of effects" (p. 40). Two diametrically opposed orientations to visual design have arisen from the concept of pictorial stimulus complexity, one element in Salomon's (1974) proposed taxonomy.

Hoban, Hoban, and Zisman (1937) proposed that the instructional effectiveness of visual resources depended in part upon the degree to which they approached the reality of experience. According to Norberg (1966), this notion helped set a pattern followed in the audiovisual literature for thirty years. Travers (1964) noted that this proposition had almost the status of a cornerstone in the audiovisual field. Dwyer (1978) collectively entitled this set of theoretical positions as the "realism" theories. Basically, these orientations contend that the more nearly a visual representation resembles its referent (i.e., the higher its "iconicity"--Morris, 1946), the more effective it will be for most instructional purposes. The realism theories encompass Carpenter's (1953) sign-similarity hypothesis and Dale's (1946) Cone of Experiences. Miller (1957) tied a basic principle of stimulus-response theory, stimulus generalization, to the realism position.

The relevant cue hypotheses represent the opposite principle. These hypotheses contend that a reduction of stimulus complexity is beneficial for most learning (Hartmann, 1961; Levie, 1973; Miller, 1957; Rudnick, Porter, & Suydam, 1973; Travers, 1964). Travers (1964) has suggested that "the emphasis on realism . . . is the worship of a false God" (p. 380). The relevant cue position has its origins in information theory and the concept of a limited channel capacity in humans for processing sensory stimulation. The relevant cue idea is congruent with Broadbent's (1958) conclusion that the perceptual system functions as a single channel system accessible to only one source of information at a time. According to Travers (1964), the nervous system handles a wealth of detail by simplifying it.

Miller (1957) described the essential dilemma involved in the two opposing positions. He noted that methods of directing attention to the relevant cues will invariably involve a departure from strict realism and come into conflict with the principle of stimulus generalization. Thus far, neither position has been fully supported by the research (Hedberg & Clark, 1976). Moreover, as Travers (1964) pointed out, "The position of the research scientists and the designers of audiovisual materials are at such opposite poles that it hardly seems possible that both can be correct" (p. 375).

RELATED RESEARCH

The predominant definition of pictorial complexity within the perception research literature has been expressed in terms of the physical parameters of the stimulus. Efforts to quantify the complexity of visual forms have produced a sizable number of studies describing precise methodologies for the generation of random shapes (Attneave, 1957; Dember & Earl, 1957; Den Heyer, 1974; Den Heyer, Ryan, & MacDonald, 1975; Hall, 1969; Stenson, 1966; Terwilliger, 1963; Vitz, 1966). However, it is more difficult to quantify the physical dimensions of the pictorial content common to instructional materials with this same degree of precision. Bergum & Flamm (1979) suggested that bidimensional complexity measures, of the type employed in the evaluation of random figures, may be inadequate for judging the complexity of pictures with tridimensional characteristics: "A complicating factor in the quantification of figural complexity is the matter of how to evaluate depictions of animate objects" (p. 194). Moreover, the thematic complexity, the learner's subjective impressions, or the illustration's function may be more important considerations than the physical parameters in judging instructional effectiveness (Duchastel & Waller, 1979). Nonetheless, variations in the amount of realistic detail, including color, have been the most frequently used method for defining pictorial stimulus complexity in still visuals of an instructional nature (Dwyer, 1978).

Many studies have documented the effects of pictorial complexity on subject preferences in both the research literature on perception (Berlyne, 1958; Dember & Earl, 1957; Hershenon, Munsinger & Kessen, 1965; Vitz, 1966; Wright & Gardner, 1960), and instructional media (Bloomer, 1960; Ibison, 1952; MacLean, 1930; Rudisill, 1952). However, there is a fallacy in basing visual design decisions on subject preferences. Bloomer, 1960; Dwyer, 1971, 1978; Lumsdaine, 1963; Otto and Askov, 1968; and Travers and Alvarado, 1970 have documented that desired instructional outcomes have not been consistent with the expressed preferences for a particular level of pictorial complexity. The research results do suggest that at least two variables (subject age or grade level, and amount of exposure time) interact with the complexity of visual displays to produce differential learning effects.

Subject Age

Studies have shown that rapid increases in pictorial learning skills occur from pre-school through the elementary years. The difficulties of young children with pictorial materials have been demonstrated through inadequate eye movement patterns (Mackworth & Bruner, 1970), and through problems in interpreting dimensional cues and spatial relations (Asso & Wyke, 1970; Brown, 1969).

Elkind, Koegler, and Go (1964) have shown that parts of a picture are perceived at an earlier age than wholes. This result is consonant with Piaget and Inhelder's (1956) finding that young children will reproduce outlines accurately but will improperly locate details within a drawing.

Travers (1969) used subjects varying in age from four to twelve years and discovered a tendency for young children to latch onto one particular object in a picture when presented with repeated short exposures, and to fail to observe other details. Travers also observed a marked improvement across age groups in the ability to report dynamic features of an illustration. Moore and Sasse (1971) used subjects at the third, seventh, and eleventh grade levels and observed a statistically significant difference across grade levels in the amount of immediate recall of picture content.

Stimulus Exposure Time

Levie (1973) has said that "whether it is advisable to reduce the cues to only those which are crucial to the primary learning task . . . or to provide additional cues . . . is largely a function of the amount of time allowed to study the display" (p. 41). Dwyer (1978) and his associates have conducted over one hundred studies on the effectiveness of different types of illustrations. These studies indicated that with fixed exposure times (e.g., experimenter-controlled slide presentations), line drawings have been most effective, while with non-fixed exposure time (e.g., programed instruction), realistic photographs were more effective (Hedberg & Clark, 1976). Corroborating evidence is provided by Hunter (1943), who found that the time required to learn information in a visual display is, in part, dependent upon the complexity or quantity of information it contains, and by Grover (1974), whose data revealed that the recall of complex stimuli improved significantly as the duration of exposure time increased.

Several authors have attempted to draw conclusions from the many studies dealing with pictorial complexity. Dwyer (1978) summarized his own systematic series of studies on color and realistic detail in still visuals and concluded that these variables are differentially effective, depending on the type of learning outcome.

Other researchers have formed conclusions on the basis of only partial examination of nonrandom and perhaps unrepresentative samples of studies on the topic. Levie (1973) noted that research comparing pictures varying in gross respects (e.g., photographs versus line drawings) usually provide no evidence of differences in learning. The value of realism has been questioned by Boguslavsky (1967), Attneave (1954), Devor and Stern (1970), Gorman (1973), and Rudnick, Porter, and Suydam (1973). On the other hand, support for high iconicity has been provided by Bevan and Steger (1971), Koen (1969), Nelson (1971), Smith (1964), and Spaulding (1955, 1956). Still others have provided evidence which is not so clearcut (Vandermeer, 1954; Fonesca & Bryant, 1960). In reviewing the research findings, Huggins and Entwisle (1974) declared that "more knowledge about the principles of iconic communication is needed" (p. xi).

With respect to graphics in instructional materials, MacDonald-Ross and Smith (1977) concluded that research results have been sufficiently confusing and contradictory and furthermore, that "some kind of preliminary sorting-out is necessary before we can proceed to a 'science of visual instruction'" (p. 5). Burton (1979) proposed a decreased emphasis on *confirmatory* research which tests hypotheses, and has suggested that this "sorting-out" could be accomplished through *exploratory* research which generates hypotheses through an examination of existing research data.

Through the years there have been frequent calls for research syntheses or integrations (Broudy, 1970, 1972; Clark & Angert, 1980; Kuhn, 1962; Petrie, 1976; Randhawa, 1978). Meta-analysis techniques (Glass, 1977) are the most recently developed methodology for accomplishing research integration. Glass has suggested that these techniques are particularly well-suited for resolving controversies arising from conflicting research results. A more conservative approach, however, would be to consider research integration as a form of exploratory rather than confirmatory research.

STATEMENT OF THE PROBLEM

Two distinct but related problems have caused concern within the applied field of educational technology. First, disappointment with much instructional media research has created a sizable literature dealing with media research difficulties and with suggested improvements. Inadequate conceptualization of experimental variables has been frequently blamed for conflicting media research results. Second, concern has been expressed about the decreasing interrelationship between communication theory and educational technology research. Many educational technology researchers have failed to focus on the commonalities that exist among communication models. As a result, some conceptual problems in instructional media research can be traced to a failure to define variables in terms peculiar to communication theory.

One consequence of the above shortcomings is that guidelines for the selection and/or design of instructional materials are often inprecise or contradictory. The conflicting positions of the research scientists and the designers of audiovisual materials have been pointed out.

One proposal has been to increase the emphasis on research which generates hypotheses. Research synthesis, or integration, has been suggested as a methodology for implementing this solution. In addition, researchers have proposed integration as a necessary first step in establishing new media directions. Research integration studies which proceed with variables defined in terms commensurate with communication models could help reaffirm the linkage between communication theory and educational technology. Further, such studies could generate hypotheses with soundly conceived variables.

PURPOSE

The purpose of this study will be to generate hypotheses based upon the results of a research integration. This investigation will be limited to the body of research utilizing still iconic visuals in instructional materials. Major emphasis will be on studies which have varied pictorial stimulus complexity by manipulating the stimulus attributes of color and detail. The influence of subject age and stimulus exposure time, type of learning outcome, and methodological adequacy of the studies will be examined with respect to instructional effectiveness.

METHODOLOGY

This investigation will proceed in five phases:

Phase 1--Establishment of Criteria

Both methodological and conceptual characteristics of the studies will determine their eligibility for inclusion. The following criteria are tentatively proposed:

1. Studies must have been experimental or quasi-experimental in nature (Isaac & Michael, 1971). Pilot studies will be excluded from consideration.
2. Studies must have utilized human subjects without physiological, sociological, or psychological deficiencies. An assumption of normality will be made for these conditions unless specific information to the contrary is indicated.

3. Studies must contain quantitative data sufficient for the computation of effect-sizes, estimates of effect-size, or "pseudo" effect-sizes (Glass, 1977).
4. The "type" of illustration in the treatment must be readily identifiable or specified within each study. Further, the "type" of illustration must remain constant within each treatment.
5. Studies must have used dependent measures which could be considered instructional in nature.
6. For studies utilizing multiple dependent measures, a dependent measure must be consistent within each effect-size, estimated effect-size, or "pseudo" effect-size calculation.
7. For studies utilizing multiple presentation modes or techniques, a mode or technique must be consistent within each effect-size, estimated effect-size, or "pseudo" effect-size calculation.
8. Multi-treatment studies must utilize subject matter content which does not vary among treatment groups within that study.
9. At least one experimental treatment within a study must have incorporated static iconic material of an instructional nature.
10. Studies without control groups will be included if:
    (a) pretesting was a design feature of the study.
    (b) the computation of "pseudo" effect-sizes is possible.
11. Studies with untreated control groups will be included if the computation of "pseudo" effect-sizes is possible.

12. Studies incorporating pretesting and no control groups will be included if:
    (a) effect-size computations are not based on pre-test/post-test comparisons,
    (b) experimental treatments compared the different static iconic visuals or,
    (c) evaluated the effect of adding static iconic visuals to digital treatment content.

Phase 2--Collection of Relevant Literature

Standard bibliographic search procedures will be used to locate potentially pertinent studies. In addition, automated information retrieval services will be utilized to locate potential studies from the ERIC, Psychological Abstracts, and Dissertation Abstracts data bases. This initial pool of studies will be reduced through a screening process involving the application of the criteria established in Phase 1. The remaining relevant studies will comprise the sample for this investigation (Jackson, 1978). The conceptual relationship of this body of studies to parallel areas of investigation will be established.

Phase 3--Identification and Classification of Variables

Studies will be analyzed and coded for the following characteristics:

1. Illustration type will be coded in three ways. Visuals will be chirographic or photographic (Gibson, 1953), pictorial, iconic, or analogic (Knowlton, 1964); and either line drawing, cartoon,

shaded drawing, model photograph, referent photograph, or painting (Dwyer, 1978).

2. Chroma will be coded as either black and white, realistically colored, or unrealistically colored. An assumption of realism will be made for illustrations specified as colored unless information to the contrary is indicated.
3. Subjects will be coded as to grade level. Grade-level transformations will be made when subject age is specified.
4. Stimulus exposure time first will be coded dichotomously in terms of locus of control. An additional classification of high, medium, or low exposure time will be applied to those studies where multiple exposure times have been a researcher-manipulated variable.
5. Learning outcomes will be classified in accordance with Bloom's (1956) taxonomy (see Isaac & Michael, 1971).

In addition, the type of effect-size computation, (true effect-size, estimate of effect-size, or "pseudo" effect-size) is directly related to the experimental designs and data reporting procedures of the studies of interest. Thus, the effect-size measures will be coded as to method of computation. Also, a large proportion of the studies in question have been undertaken either by one individual (Dwyer, 1978) or by various colleagues using similar materials and procedures. Since experimenter bias could seriously affect the analysis, a distinction will be made between studies performed by Dwyer or associates and other investigators by coding these studies dichotomously.

Phase 4--Analysis of Data

The units of analysis in this investigation will be the effect-size comparisons, estimates of effect-size, and "pseudo" effect-size calculations from each research study. A combination of meta-analysis techniques (Glass, 1976, 1977) and descriptive statistics will be used to achieve a quantitative aggregation of the findings of the sampled studies. The descriptive relationships among the effect-size measures and the coded variables will be examined by graphic displays of various crosscuts of the data. Frequency curves, scattergrams, and crossbreaks will be used for data display (Isaac & Michael, 1971). The analysis will be performed by using the appropriate routines from SAS (Barr, Goodnight, Sall, & Helwig, 1979).

Phase 5--Identification of Hypotheses and Needed Research

The results of the data analysis will be used to synthesize the current state of knowledge regarding static iconic visuals in instructional materials with respect to the coded variables. The following four kinds of information will result:

1. The generation of sample hypotheses derived from effect-size comparisons. These shall serve as exemplars of hypothetical relationships among the coded variables of this investigation.
2. A clarification of the theoretical framework guiding this investigation through verbal analysis and graphic description.
3. The establishment of priorities for further individual research efforts. These shall be based upon variables and relationships suggested by previous theory or research, but

for which there is inadequate evidence due to either a lack of study or from conceptual weaknesses within the sampled studies.

4. The establishment of priorities for further research integrations derived from the theoretical framework.

LIMITATIONS, DELIMITATIONS, AND ASSUMPTIONS

This investigation will be undertaken with some limitations, delimitations, and assumptions which are peculiar to research integration studies. To a large extent, research synthesis or integration is limited by the characteristics of the pre-existing studies. Typically, rigorous control is lacking over the conceptualization of variables, the methodology, the data analysis, and the data reporting procedures within the body of studies to be integrated. Consequently, integrations can be undertaken only in terms of variables which are codable for all studies and in terms of variables which, by their definition, impose some degree of uniformity on the characteristics of these studies. This means that some precision must be sacrificed in extracting information from the studies and that the subsequent analysis may not be as powerful or as finite for the body of studies as it could be for an individual study.

This study will be conducted with five delimitations. First, the relative effectiveness of digital versus iconic coding of information in instructional materials is not the concern of this study. However, subject to the criteria previously listed, studies which have raised this issue as a major research question may be included in the present study.

Second, pictorial stimulus complexity is defined in this study only in terms of two physical pictorial attributes (detail and color). Other attributes (e.g., dimensional cues, redundancy) may indeed contribute to the level of complexity; however, investigations of these attributes are not nearly as numerous and may not warrant the use of the proposed meta-analysis techniques.

Third, this investigation will be delimited by integrating only studies in which the iconic content was composed of static visuals. Motion, as one aspect of iconicity, is not a resource attribute of interest to this investigation. However, studies in which the presentation of treatment content was accomplished with motion picture projection equipment may be included if the projected material is of a static rather than a dynamic nature.

Fourth, this investigation will not focus on the use of embellishments (e.g., arrows, captions, bold lines) or other cues which attempt to increase the effectiveness of iconic materials.

Several assumptions have been made which could have a bearing either on the results of this investigation or on their interpretation. First, the proposed criteria are presumably specific enough to delineate the studies of research interest, but not so restrictive as to eliminate studies which would otherwise merit inclusion. Second, the body of studies to be integrated is presumed to be a representative sample rather than a population (Jackson, 1978), despite the use of thorough bibliographic search procedures. Third, meta-analysis techniques are assumed to be suited to research integration, and methodologically superior to narrative reviews of literature (Glass, 1977). Fourth, the increased specificity of the data collected from the application of meta-analysis procedures is presumed to be more appropriate for the generation of specific hypotheses than are other quantitative methods (Jackson, 1978), or narrative summations. And fifth, it is assumed that the processes and variables peculiar to communication theory and to communication models are more appropriate than other theoretical orientations for synthesizing the results from the proposed body of research.

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