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AUTHOR Fleming, Malcolm
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ABSTRACT

In a framework of cognitive theory, an exploratory study examined eye movements of learners studying print materials combining text and illustrations. Eye movement patterns were used as indicators of the cognitive strategies employed. Both design and learner variables were emphasized. Twenty-four graduate education students were randomly assigned to each of two page layout treatments. Design variables were text complexity (simple or complex) and page layout (either picture first and then words or words before picture). Learner variables were sex, cognitive style (field dependence/independence), and prior knowledge. The dependent variable was visual attention indicated by eye movement data including duration, transitions, and sequences. Subjects studied the material while fitted with head-mounted eye movement detecting equipment. Of the design variables, the complexity factor was most determinative of learner strategy. Of the learner variables, cognitive style and sex were reliably associated with learner strategies, but prior knowledge had no effect on strategy. In an analysis of the complex page, results revealed a tendency for females to favor the given order and males the reverse. Six references are listed. (LMM)

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AUTHOR: Malcolm Fleming

To: Mike Scriven
From: Mac Fleming

Visual Attention to Picture and Word Materials as Influenced by Characteristics of the Learners and Design of the Materials.

Purpose. The long range goal of this program of research is to improve the match between the design of instructional materials and the characteristics of learners. Particular attention is on the cognitive strategies which skilled learners employ in the study of materials combining words and pictures.

Theoretical interest centers on the fact that recent research on verbal and imaginal processing suggests that words and pictures are cognitively disparate, requiring different kinds and amounts of processing. This implies potential cognitive problems where words and pictures are mixed indiscriminately in instructional materials.

What follows was an exploratory study of how skilled learners cope with materials combining words and pictures, e.g., textbooks.

Background. This study was done in a framework of cognitive theory. It specifically examined the eye movements of learners studying print materials combining text and illustrations. The eye-movement patterns were seen as useful indicators of the cognitive strategies employed. (There is ample precedent for this interpretation of eye-movement data, e.g., Snow, 1968; Just and Carpenter, 1980; Farnham-Diggery and Gregg, 1975) Strategies were inferred from the differential duration of attention to word

and picture areas and from the numbers and patterns of transitions between areas.

The writer ascribes to a constructivist model of reading, where reading comprehension involves the reader's search for meaning from the author's words as well as his diagrams, graphs, pictures, etc. Meaning is constructed by the reader both from what the material provides and what the reader provides from his/her own world knowledge. The skilled (university-level) reader's prior knowledge includes strategies for studying and schema for interpreting and remembering various kinds of materials, e.g., stories, expository text, research articles, science diagrams, pictorial scenes, etc.

Research to date on reading comprehension has examined primarily the words (prose learning), to a lesser extent the illustrations (picture learning), and rarely both in interaction (textbook learning). This both explains the preponerance of prose learning concepts in what follows and justifies the current study of strategies involving both text and illustration.

Much has been made of the differences between word processing (linear, digital, symbolic, left brain, visual and auditory modalities, learned skill) and picture processing (simultaneous, analogic, concrete, right brain, visual modality, less learning). Clearly there are processes specific to each, but on a typical page combining both they must somehow be integrated. A macrostructure (theme, gist) must be constructed that includes both. Apparently, these diverse elements are

integrated primarily at a higher semantic lev

Reading theories differ in degree of emphasis on what information is given in the text as compared to what is brought to it by the reader. Those emphasizing meaning-in-the-text are remindful of the position of many audiovisual professionals, i.e., the meaning is in the medium, especially the pictures. Both emphasize the given stimulus, whether word or picture. In contrast, the reading constructivist theories which emphasize the interaction of reader characteristics, context, and print are remindful of the aptitude (or trait) treatment interaction theorists in instructional development. Both emphasize the differential outcomes from what's given depending on the learner's prior knowledge, interests, skills, etc.

The above suggests the two sets of pertinent variables which this study investigated, i.e., what's given (design variables) and what the learner brings to it (learner variables). One of the design variables (what's given) often cited in reading comprehension research is context, i.e., the verbal context on the page. In the present analysis of realworld instructional materials it is apparent that words in textbooks often provide context for pictures, e.g., interpretive captions, and pictures often provide context for words, e.g., pictured examples of concepts. Often the intended relation between text and illustration appears ambiguous. Where one appears above the other on a page, do readers assume that the one provides a context for what follows? The question of page-layout order,

i.e., which comes first, words or pictures, was examined in this study. Different cognitive strategies were expected for the two page-layouts, WP and PW, but the direction of those differences was not predicted.

Another of the design variables common in reading research is complexity, which is often operationalized according to a readability formula involving word length or frequency, sentence length, etc. Complexity has also been variously operationalized in picture studies by number of figures, degree of realism, etc. In this study complexity was operationalized in two ways: grade level of the materials and length of sentences. It was predicted that cognitive strategies for complex materials would include longer study durations and more transitions between areas than for simple materials.

Common measures of learner characteristics in reading studies are proficiency tests, e.g., vocabulary or comprehension. The present study using graduate students assumed high reading and study skills. However, the sample was divided by sex because it was hypothesized that word/picture study strategies of males and females might differ. The evidence that women tend to have higher verbal skills (Lips and Colwill, 1978) as well as higher grades in general (Maccoby and Jacklin, 1974) was the basis for predictions of greater attention to words and longer overall study duration for women than men.

Another learner characteristic studied here was cognitive style, specifically field dependence-field independence. The

evidence that field dependents tend to be more global and field independents more analytical (Witkin, et al, 1974) led to the prediction that global field dependents would follow (be dependent on) the given pattern of information on the page, whereas the more analytical field independents would tend to deviate from (be independent of) the given pattern.

World knowledge is considered to be an important factor in reading comprehension. In the present study an attempt was made to estimate the prior knowledge of the learners about the subject matter, biological science. It was predicted that the more knowledgeable learners would have study strategies which were shorter in duration and which involved fewer transitions between areas than would less knowledgeable learners.

Procedure. A convenience sample of 24 students was selected from a graduate class in Education such that half were males and half females. Half of each sex grouping were randomly assigned to each of two page-layout treatments.

The design variables were complexity at two levels, simple v.s. complex, and page layout at two levels, picture first and then words (PW) v.s. words first then picture (WP). See Fig. 1 for an example of a PW layout. The simple material was from an 8th grade text, while the complex was from a scientific research journal. They contained comparable numbers of words, but sentences in the complex material averaged about twice as long. The learner variables were sex, cognitive style (field

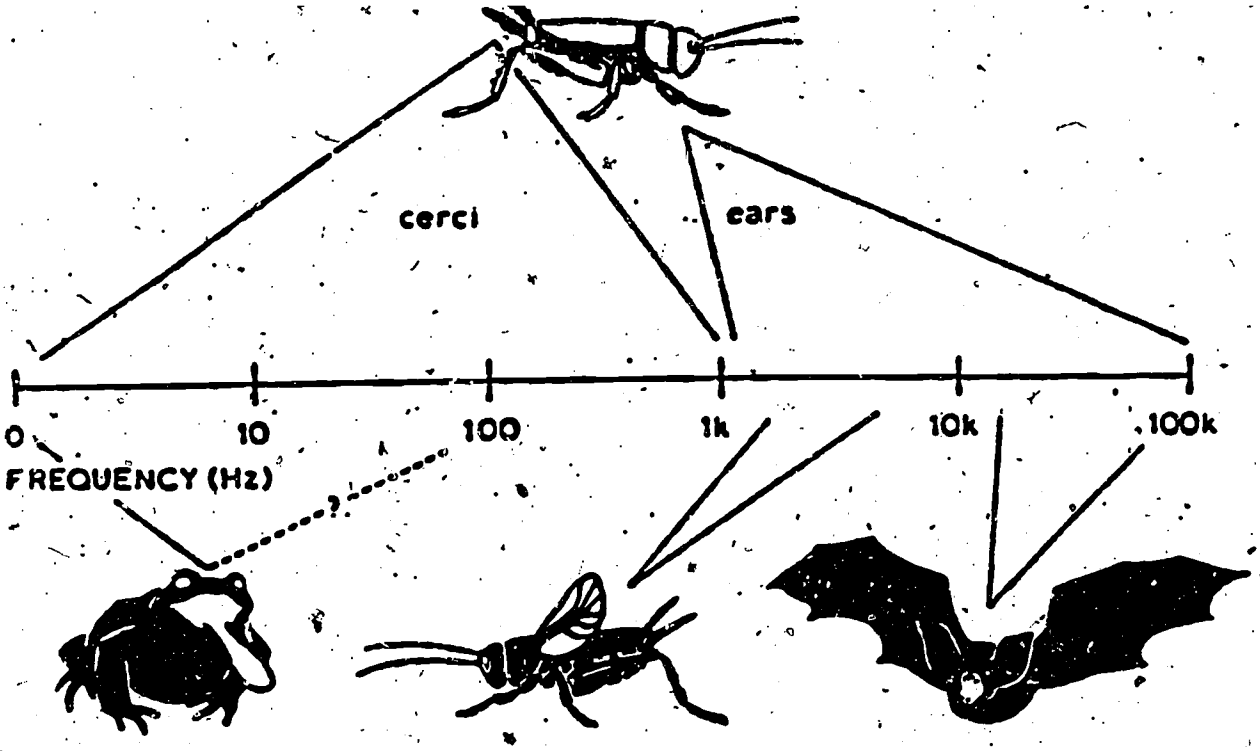


FIG. 2 The range of hearing in field crickets. The frequency line is drawn logarithmically, from zero Hertz (0 Hz), through the infrasound and terminating in the ultrasound at 100,000 Hz (100 kHz). Low frequency stimuli are detected by the cricket's cerci, and higher frequencies are detected by its tympanal organ or "ear." Below the frequency line are drawn typical sources of sound that fall within the cricket's range of audition: terrestrial predators such as frogs produce low frequency vibrations, crickets produce middle frequency vibrations, and flying bats produce ultrasound.

Recognizing Predators by Ear: The Pitch Is the Switch

In its world a cricket hears not only other crickets, it hears potential predators. Crickets are sensitive to a surprisingly wide range of frequencies; in fact, the frequency band devoted to social communication is only a narrow one considered in light of the insect's auditory capabilities. Figure 2 shows a frequency range from zero Hz to 100,000 Hz—from infrasound to ultrasound. Crickets are sensitive over a good part of this range; compare this with the auditory sensitivity of humans, which spans a range of 50 Hz to 15,000 Hz.

Figure 3A–C shows diagrams taken from photographs of flying crickets responding to acoustic stimuli. In the absence of sound a cricket flies with a symmetrical flight posture, with its longitudinal body axis perfectly straight. When a series of sound pulses consisting of pure 5 kHz tones is played from a speaker on the cricket's left, the insect bends its abdomen and legs to the left, a rudder-like action that would propel the insect toward the speaker, were the insect not tethered. However, when the sound pulses are composed of 40 kHz tones, the cricket's abdomen and legs abruptly veer to the right; in free-flight this would propel the cricket away from the sound source. Thus, 5 kHz tones elicit positive phonotactic movements and 40 kHz cause negative phonotactic movements. The sign of the movements makes behavioral sense: 5 kHz is the carrier of frequency of the calling song of *Teleogryllus oceanicus*; female crickets are attracted to this frequency. Forty kHz is in the ultrasonic range and occurs in the vocalizations produced by insectivorous bats (Griffin, 1974); crickets attempting to escape from echolocating bats would be expected to react to 40 kHz aversively.

The frequency sensitivity of steering behavior can be ascertained by examining a behavioral tuning curve (Fig. 3D) made by measuring the threshold sound intensities required to elicit a phonotactic response as a function of the tone frequency. *T. oceanicus* is most responsive to tones in the range 4–6 kHz, with peak sensitivity at 5 kHz; a second area of sensitivity occurs in the ultrasound, from 25–100 kHz.

FIG. 1.

dependent/field independent), and prior knowledge.

The dependent variable was visual attention as indicated by eye-movement data, specifically the amount of time spent attending to each area of the materials (duration), the number of shifts between areas (transitions), and the pattern of transitions (sequences).

Subjects were instructed to study the material as though it had been assigned for them to understand and remember. They were then fitted with head-mounted eye-movement-detecting equipment (NAC Eyemark IV). They were allowed as much time as needed to study the materials.

Subjects then completed a brief questionnaire concerning the relative familiarity and difficulty of the materials and the number of related courses (biology) which they had taken. They then took a cognitive style test, the GEFT (Group Embedded Figures Test).

Raw data records consisted of videotape recordings showing the stimulus a subject was studying plus a superimposed marker which indicated just where on the stimulus the subject was looking at any moment. The four pages of stimuli were divided into 30 significant areas, i.e., either figures in the pictures or captions and paragraphs in the text. Read out from the videotape records were the duration of attention to each area and the number and sequence of transitions between areas. Twenty of the 24 records were usable.

Results:Overall. A 3-way ANOVA of the effects of Sex and Layout (independent measures) and Complexity (repeated measure) on total transitions revealed the predicted signficant main effect for complexity, $p<.001$, but no effect for sex or layout. Subjects made more transitions in studying the complex material than the simple.

Analysis of the effects on total duration revealed significant differences, as expected, for both sex, $p<.004$, and complexity, $p<.001$. Females attended longer overall to the study materials than did males. All subjects studied the complex materials more than the simple.

There was no main effect for layout (PW v.s. WP) nor for prior knowledge. Analyses of the data relative to familiarity of the content as well as number of biology courses taken revealed no significant relationships to cognitive strategy.

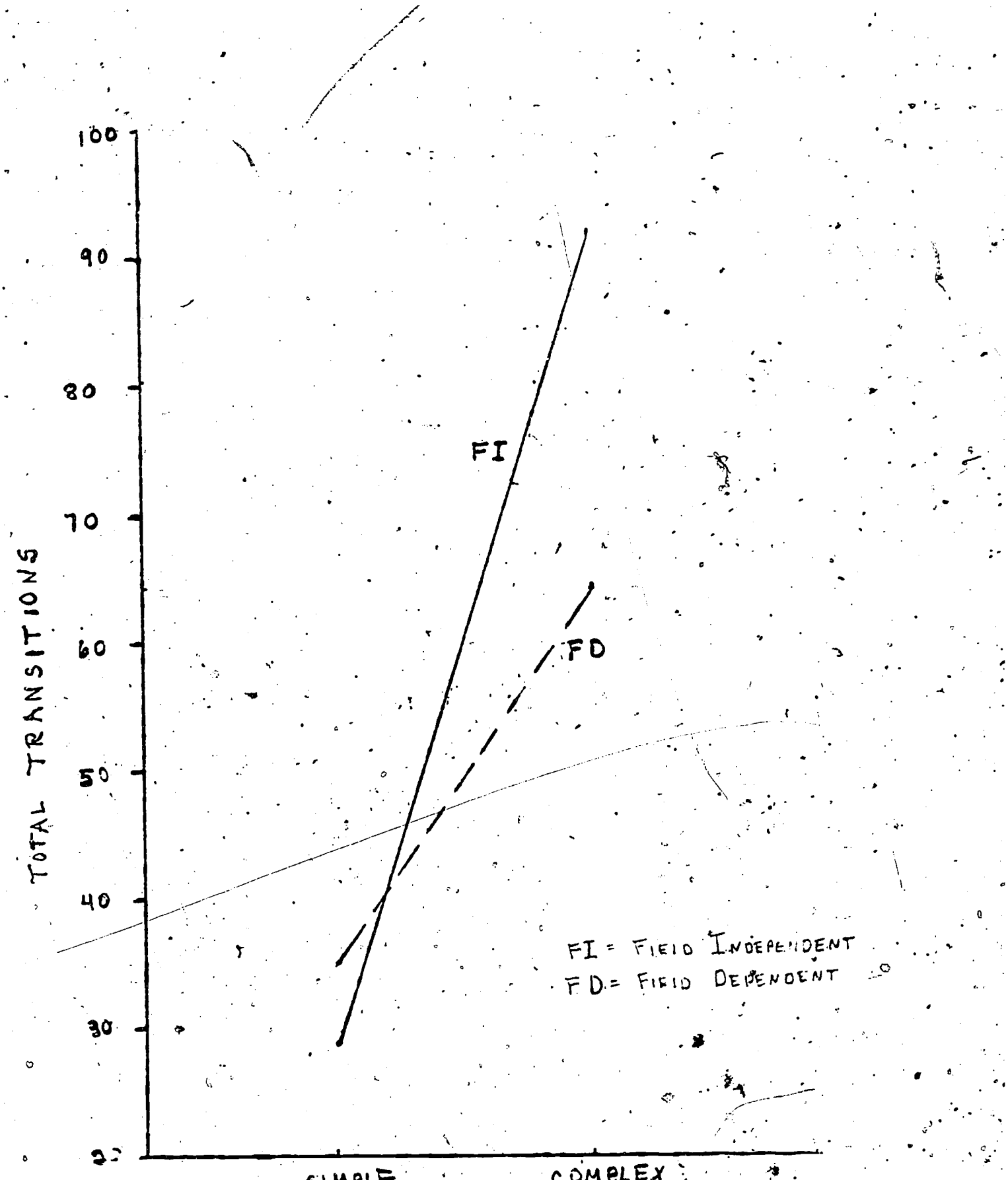
There was a significant positive correlation between cognitive style (GEFT) and number of transitions for complex materials only (Spearman $p<.034$. Kendall $p<.037$). So, a median split was made of the subjects by GEFT score and two groups formed, higher scorers (Field Independents) and lower scorers (Field Dependents). An ANOVA revealed a significant two-way interaction between cognitive style and complexity, $p<.003$, for transitions. While subjects of both cognitive styles made more transitions on complex materials than on simple, the field independents made a larger adjustment to complexity, i.e. they made relatively fewer transitions for the simple and relatively

more transitions for the complex materials than did the field dependents. See Fig. 2.

Results:Complex Material. Because subjects' strategies seemed most influenced by the complexity factor, it was decided to analyze the most complex page further. A 3-way ANOVA, Page Layout by Sex by Sequence, revealed a significant main effect for sequence, $p<.05$. There were, of course, more transitions in the given sequence (top down) than in the reversed. However, there was a significant 2-way interaction between sex and sequence, $p<.05$ the females favoring the given order and the males the reversed. This was further modified by a 3-way interaction involving page layout, which revealed that the tendency for males to make more reverse order transitions was limited to the WP layout condition (words first, then pictures). See Fig. 3.

The above interactions suggest a very interesting possibility. Assume that a compatible match of cognitive strategy and page layout would show up as a largely straight through (top down) attention sequence, i.e., a minimum number of transitions and most of these in the given order. It follows, according to this assumption, that the most compatible layout for males was [redacted] and for females WP. See Fig. 3 for the curves with a low overall number of transitions and with more in the given than reversed order.

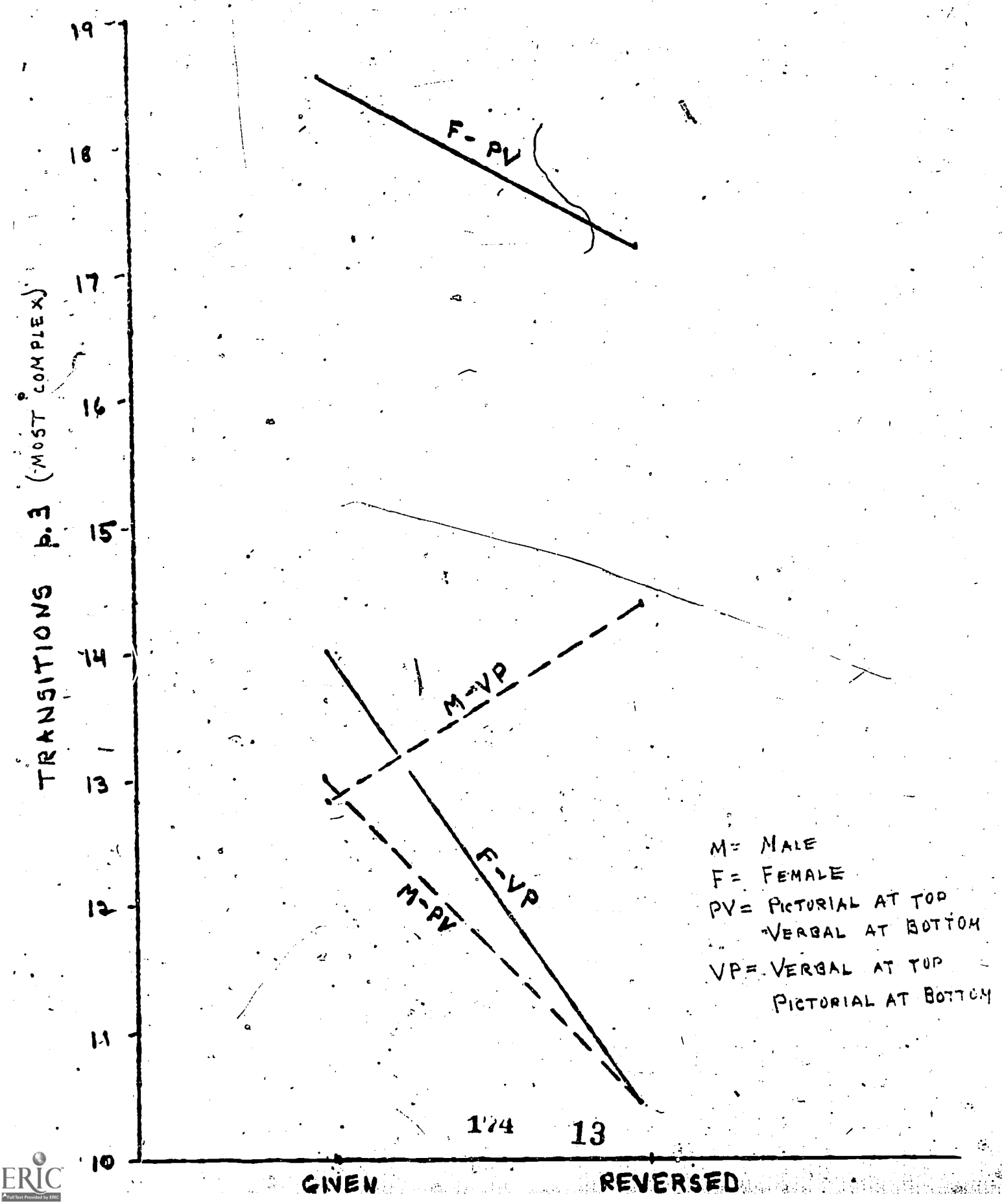
A further analysis was made of attention patterns to the five pictorial areas, two related verbal areas, and one caption


100
90
80
70
60
50
40
30
TOTAL TRANSITIONS
FI
FD
FI = FIELD INDEPENDENT
FD = FIELD DEPENDENT
SIMPLE
COMPLEX
MATERIALS

173

FIG. 2. 12

FIG. 3


TRANSITIONS p.3 (MOST COMPLEX)
19
18
17
16
15
14
13
12
11
10
F-PV
M-VP
F-VP
M-PV
GIVEN
REVERSED
M= MALE
F= FEMALE
PV= PICTORIAL AT TOP
VERBAL AT BOTTOM
VP= VERBAL AT TOP
PICTORIAL AT BOTTOM

area on the complex page. A 2-way ANOVA, Sex by Layout, revealed no differences in attention to picture areas but a significant difference in attention to verbal areas, $p<.05$. As predicted, women made more transitions to verbal areas and maintained attention there longer than males. For the caption area there was a significant effect for layout, there being more transitions to the caption, $p<.01$, and longer durations on the caption, $p<.05$, for the PW layout than for the WP layout. This is understandable because the PW layout put the caption in the middle of the page where it was more noticeable, whereas the WP layout put it at the bottom.

Another analysis of the complex page, Cognitive Style by Layout, revealed no differences for the verbal areas but significant differences for pictorial areas, $p<.05$ for durations and $p<.01$ for transitions. Field independents looked longer and more often at picture areas on the complex page than did field dependents. This was not predicted.

Conclusions. Of the design variables, the complexity factor was clearly the most determinative of learner strategy. Of the learner variables, prior knowledge had no effect on strategy. Perhaps the measures of prior knowledge were inadequate. The other learner variables, cognitive style and sex, were reliably associated with learner strategies.

These main effects and interactions with cognitive style and sex were largely as predicted from prior research and theory.

However, there were some surprises, e.g., the effect of cognitive style on strategy adaptation to instructional material complexity, and the effect of sex on strategies for sequencing attention to words and pictures.

Clearly, more such studies are needed to confirm or disconfirm these conclusions. However, the results do suggest that the design of science materials for graduate students may need to take account of two learner variables, sex and cognitive style, and two design variables, complexity and picture-word layout.

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