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ABSTRACT

Reported is an Aptitude Treatment Instruction (ATI) Study designed to evaluate the aptitude of verbal comprehension in terms of two unitary complex science diagram types: a single complex block word diagram and a single complex picture word diagram.. ATI theory and research indicate that different effective instructional treatments tend to help some kinds of learners more than others. These findings have cost, facility, and personal implications for the design and implementations of science curriculums and the development of individualized instructional programs. Eighty-two high school science subjects were randomly assigned to a word or word-picture diagram (i.e., pathway or cyclic schema with adjunct questions) treatment. Multiple regression analysis of posttest scores (predictors: verbal ability and pretest scores) supported the a priori hypothesis that low verbal subjects seemed to benefit from certain verbal and pictorial referents. Higher verbal ability subjects appeared to be less dependent on the investigated pictorial referent type in terms of the verbal (nonpictorial) criterion test. (Author/PEB)

DIFFERENTIAL EFFECTIVENESS OF TWO SCIENCE DIAGRAM TYPES

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INTRODUCTION

Aptitude Treatment Instruction (ATI) theory and research indicate that varying instructional treatments differentially effect different learner types. Such findings have cost, facility and personnel implications for the design and implementations of science curriculums and the development of individualized instructional programs. ATI relationships are investigated by measuring those aptitudes (i.e., learner characteristics) that theoretically relate to different instructional treatments and criterion tasks. (Cronbach, 1967). Koran, Snow and McDonald's (1971) ATI investigation of differing procedures leading to the acquisition of teaching skills has been the prototype study used by many researchers in their examination of ATI relationships. Dr. J.J. Koran, Jr., has been the leading ATI researcher in science education as exemplified in his recent study of differentially structured advance organizers in science instruction.(Koran and Koran, 1973).

Factorial studies have provided science educators with multi-dimensional aptitude instruments which can be used to quantify certain learner characteristics in secondary school science studies. In the simplest case, the following experimental procedure is performed: 1) an aptitude test is administered 2) subjects are randomly assigned to one of two instructional treatment conditions; and 3) a dependent variable is measured. ATI experimental data is analyzed in terms of multiple regression analysis which can be expressed in a graphic display of lines that "best fit" the aptitude and criterion data.

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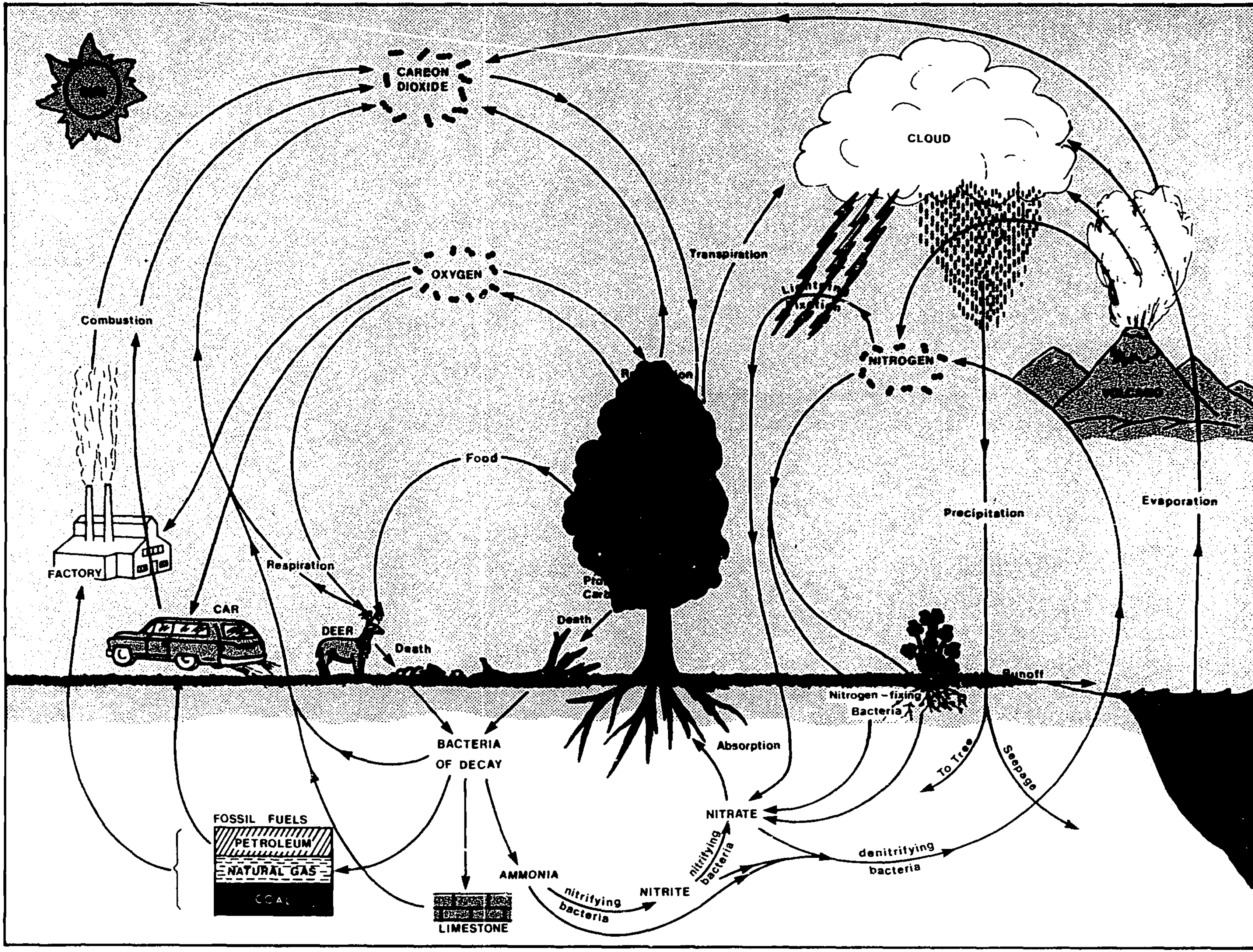

CARBON DIOXIDE
OXYGEN
CLOUD
NITROGEN
Combustion
Transpiration
Food
Respiration
FACTORY
CAR
DEER
Death
Death
Precipitation
Evaporation
Runoff
Nitrogen-fixing Bacteria
To Tree
Seepage
Absorption
BACTERIA OF DECAY
NITRATE
NITRITE
AMMONIA
nitrifying bacteria
nitrifying bacteria
denitrifying bacteria
FOSSIL FUELS
PETROLEUM
NATURAL GAS
COAL
LIMESTONE

The present ATI study evaluated the aptitude of verbal comprehension in terms of two unitary complex science diagram types, specifically (i.e., a single diagrammatic presentation of distinct relationships among concepts constituting intra- and interdisciplinary science information) a single complex block word diagram and a single complex picture word diagram. The relatively inexpensive and easy-to-prepare block word diagram usually consists of words (i.e., verbal labels of concepts) and uncolored block figures (e.g., rectangles and circles) joined by arrowed lines indicating distinct conceptual relationships. The more expensive and increasingly popular picture word diagram (See page 2) usually consists of colored stylized line drawings of concrete concepts and logically positioned verbal labels of more abstract concepts joined by diagrammatic arrowed lines. The proper design and use of unitary complex science diagram apparently can facilitate the learner's ability to identify translated and rephrased sets, subsets and compound sets of certain accented conceptual relationships in terms of a prose ("non-diagrammatic") posttest. This diagram type represents a more effective instructional display under certain conditions relative to the common teacher presented and student attended to "equivalent" text description <u>or even</u> a combination of the diagram adjacent to a text. This twofold issue has been empirically evaluated elsewhere (Holliday, 1974b) and discussed in terms of instructional design implications for future science curriculum materials.

Process analysis of relevant learner aptitudes related to specific instructional treatments and criterion measures can facilitate our understanding of these relationships and provide a more refined basis for future experimentation (Koran, 1973). Melton's (1967) generalized multi-process model represents a relatively common process analysis mechanism used in previous ATI science education research (See Wilson, 1973). Holliday's (1974a) Linguistic-Pictorial Model (See Figure A), based on information processing theory and research, also, has been used to conceptualize certain science textbook picture and prose instructional stimuli and a related learner aptitude and criterion measure. Because of the nature and interrelationships of the two instructional diagram types and the aptitude under inspection the latter model has been chosen to examine and explain relevant mediational processes.

It was hypothesized that a verbal comprehension aptitude would facilitate all learners efforts to process unitary complex science diagram instructional stimuli under certain conditions in terms of a verbal posttest criterion measure. Secondly, it was hypothesized that higher verbal subjects would be less dependent upon the pictorial referents in the picture word diagram and be able to process effectively either the block word or picture word diagram. In contrast, the lower verbal subjects would be more dependent upon pictorial referents because of their deficit ability to process verbal information. These conditions hypothetically could result in less effective processing of the block word diagram, a more verbally-dependent instructional stimuli type. Verbal comprehension ability is most closely associated with the linguistic coding (LCx), and memory (LMx), components of Holliday's Model (see Figure A). As evident in the Model, lower verbal subjects would be more dependent on their pictorial coding (PCx) and memory (PCx) processes relative to higher verbal subjects in responding to certain criterion measures. The picture word diagram would allow these lower verbal subjects partially to compensate for their relative inability to code and remember verbal science information.

METHOD

Two concurrent studies were based on data gathered in a single experiment examining unitary complex science diagrams.

Subjects

Eighty-three high school students enrolled in an introductory biology course in the Calgary (Alberta, Canada) public schools constituted the sample used in the present study.

Materials

Selected biogeochemical cycles commonly presented in a secondary school science textbook constituted the treatment materials for two main reasons. First, these interdisciplinary science cycles (i.e., oxygen, carbon dioxide, water, nitrogen) contain numerous distinct conceptual relationships and represent school relevant content that has recently attracted a considerable amount of attention from developers of unified science and environmental science curriculums. Second, these cylces are commonly presented in a diagrammatic fashion as illustrated in practically all science textbooks that attend to these concepts.

Two instructional treatments and a single criterion test were used in this study. These treatments consisted of a: 1) a picture word diagram (PWD) and (2) a block word diagram (BWD). Both treatments contained the same two or three adjunct questions on each of the 10 pages of instruction. The picture word or block word diagram displayed on the ten pages were identical for that treatment (see Figure B). This repeated exposure to the same diagram theoretically reinforced a mental image of the complex diagram in the learner's mind.

The two diagram types differed in terms of the positions of the verbal labels, arrowed lines joining the labels and the associated block figures or colored drawings. Both diagrams contained the equivalent 37 concepts and conceptual relationships associated with the criterion information. Of course, the two diagrams could not be considered redundant display units because the instructional advantages and limitations of the individual medium types, a common point of confusion (Holliday, 1971). The objective in the design of the treatment materials was to present certain biogeochemical cycles in the most effective fashion given the limitations of the particular instructional display type. For example, BWD was limited to a black and white display using only block figures, verbal labels (printed words) of criterion concepts, and arrowed lines indicating criterion conceptual relationships.

The picture word diagram consisted of a colored stylized line drawings of concrete criterion concepts (e.g., tree) joined by diagrammatic arrowed lines indicating selected conceptual relationships. Verbal labels were used to clarify the meaning of most drawings. The more abstract concepts (e.g., "nitrifying bacteria" and "nitrite") verbal labels were positioned adjacent to other logically appropriate abstract concepts and drawings of concrete concepts (e.g., "nitrifying bacteria" label was positioned adjacent to the "nitrite" label and beneath the ground level illustrationed in the diagram.)

The block word diagram consisted of verbal labels, uncolored block figures (circles and rectangles) and arrowed lines indicating selected conceptual relationships. The verbal label "plant" was used to indicate any green plant in BWD and a picture of a tree represented the equivalent concept in PWD; otherwise, the verbal labels in both diagrams were equivalent.

Twenty-two identical adjunct verbal questions represented the instructive techniques used to direct the learner's attention to all learning materials in each treatment group. The questions required subjects to inspect the diagrams and identify selected distinct conceptual relationships commonly presented in both treatments.

Thirty-two multiple choice, verbal prose criterion test items were generated from translated or rephrased adjunct questions and the corresponding answers (a question set) contained in the treatments. Each posttest item required subjects to recall and identify a part or a whole, more than one question set. In other words, the correct identification of a subset, set and a combination of sets was required. Subjects ability to identify conceptual information not clearly defined in the learning materials was not evaluated in the present study.

Procedure

Two weeks prior to the present experiments, five aptitude pretests were administered and evaluated in the present study and a correlational pilot study. Subjects were led to believe that the five pretests constituted their entire contribution to this "special" testing program. The Verbal Comprehension (V-2) test (French, 1963) scores generated by the subjects were used in the present study.

Subjects were randomly assigned to the two experimental groups. They were instructed to learn the material and answer the adjunct questions. They also were told that the results of their total scores on the adjunct questions and on the subsequent multiple choice verbal text covering the biogeochemical cycles material would be a good indicator of their ability to understand science information and that scores would be communicated to their biology teacher.

RESULTS

Regression analysis of the Verbal Comprehension and posttest criterion scores resulted in a significant (F=4.46, df = 1/77, p .05) ordinal interaction (Figure B). A relatively complete description of the data (table I and II) has been provided because of the varying statistical techniques and conventions used to interpret ATI research data. One subject's aptitude score from the picture word diagram treatment group was lost.

DISCUSSIONS AND CONCLUSIONS

The differential effects hypothesis of the two unitary complex science diagrams on lower verbal subjects was supported by the experimental findings. Furthermore, higher verbal subjects were probably less dependent on the pictorial referents in the picture word diagram and were able to process both diagram types in a more effective manner.

The unitary complex science diagrams required most learners to use both linguistic and pictorial processes. The specific quantity and quality of these separate and interacting mediational processes currently is a matter of conjunction. However, repeated exposure to the diagrams through the use of adjunct verbal questions theoretically facilitated pictorial inspection behavior of both diagrams. This continuous inspection likely increased the image-evoking quality of the stimuli (i.e., the extent to which a learner can generate a mental picture of the stimuli upon demand); thereby, increasing the chance of recall. Linguistically speaking, subjects answered verbal questions based on both diagrams resulting in the facilitative recall of criterion verbal relationships as evident in the previously cited concurrent study (Holliday, 1974a). However the picture-word diagram provided verbal <u>and</u> pictorial referents to criterion concepts. These additional pictorial referents theoretically alleviated a portion of the demand placed on the linguistic mediational processes by the block word diagram. Consequently, lower verbal subjects in the picture word diagram treatment group were partially able to compensate for their relative inability to code and remember verbal science information.

These ATI experimental results should not be interpreted as confirming the hypothesis "lower verbal learners should be given science curriculum materials containing relatively more pictorial referents to criterion concepts". First, the two diagrams varied in terms of the presents of color, the nature of the figures and the arrangement of the diagrammatic arrowed lines. Second, classroom situations are multi-variant in nature. This study only examined one specific cognitive variable. Affective variants such as students' rating of enjoyment usually are considered to be educationally significant. (Baker and Popham, 1969). Evaluation of this dependent variable was investigated in another study (Holliday, 1974c). A step down multivariate analysis test supported the main effects prediction that learners in the picture word diagram treatment group generally rated the instructional experience as more enjoyable. However, because of the vague meaning of this dependent variable type, caution should be exercised by instructional designers of science curriculums in the use of such affective main effect results. Third, there exists infinate possible linguistic-pictorial science instructional stimuli and criterion measures along with many unexplored aptitudes; therefore, indiscriminate acceptance of the above hypothesis would be most dangerous. Fourth, learners using certain combinations of pictorial and verbal references (e.g., adjunct textbook pictures) can be relative more dependent upon their ability to process verbal information under certain conditions than learners given only prose material (Holliday, 1974). Therefore, science instructional decision-making cannot be totally based on such a global hypothesis. However, this hypothesis has gradational credibility in terms of the mutual proximity between a given classroom situation and the circumstances surrounding the present study. Instructional decisions about individual learners types must be flexible and influenced by ATI learning theory and research as well as feedback information, past experience and teacher value judgements (Koran and Holliday, 1974).

In conclusion, the ptoduction of science instructional materials should be a cooperative effort of research and development people in science education basing more decisions on learning theory and research. The traditional instructional design standards of historical presidence and well-meaning pedagogical intuition must be supplemented by theoretical and empirically based guidelines. Our current understanding of instructional diagrams is chiefly theoretical. Science diagrams can vary widely in terms of cognitive content, spatial organization, affective attributes and position within an instructional display. They theoretically allow instructional designers to accentuate criterial verbal and pictorial displays identifying the more relevant, distinct units and their interrelationships. Diagrams also can concentrate selected, criterion information within a more optimal learning spatial organization, thereby increasing the probability of learner attention and encoding of criterion relationships. Additional empirical investigation of science diagrams in relation to other instructional techniques, aptitudes and criterion measures clearly are worthy of our attention in the near future.

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TABLE I

REGRESSION ANALYSIS OF VERBAL APTITUDE AND CRITERION TEST SCORES[1]

Treatment Condition				
Textbook-like Pictures Adjunct and Prose		Prose Only		F
a[2]	b	a	b	
16.96	.18	8.44	.58	4.46[3]

1 Calculated crossover point on X axis = 21 on the X axis

2 a and b are of the form $\tilde{y} = a + bx$ (linear regression equation)

3 $p < .05$

TABLE II

DESCRIPTIVE STATISTICS OF THE VERBAL APTITUDE AND CRITERION TEST SCORES FOR EACH TREATMENT

Treatment	Aptitude Test			Rel.	Comprehension Test				
	$\bar{X}$	SD	Range	4	$\bar{X}$	SD	Rel.[5]	Corr.	Cases
Picture[1]					19.68	5.4		.27	41
Block[2]					17.44	6.9		.50	41
Combined	14.6	5.0	3 to 28	.52			.75		

1. Picture word diagram Treatment
2. Block word diagram Treatment
3. $p < .01$
4. Parallel Form - reliability
5. Cronbach's Alpha of internal consistency - reliability

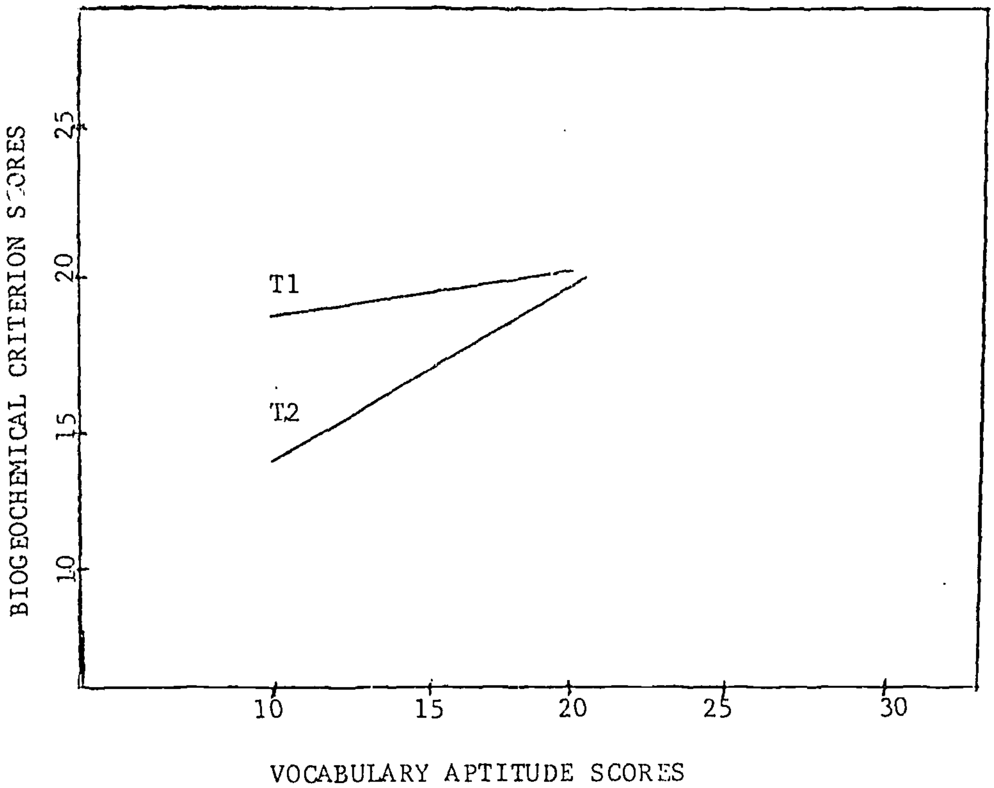

FIGURE A: ORDINAL INTERACTION SHOWING REGRESSION SLOPES

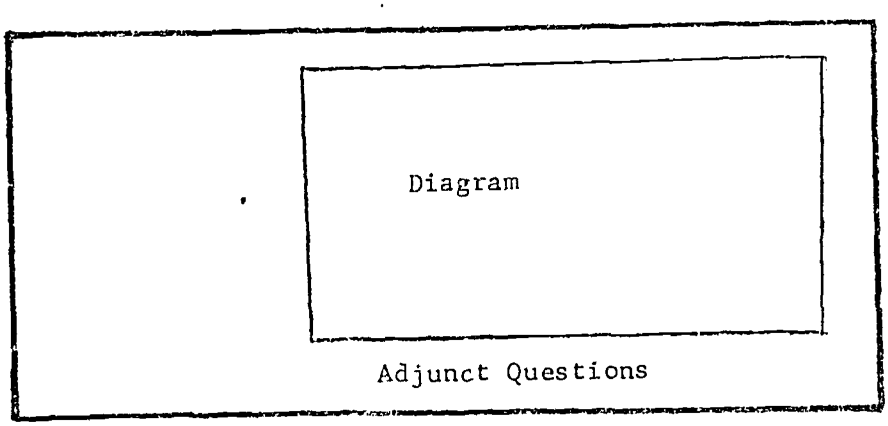

Figure B: Format of one page from the Treatment Materials