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COMPUTER-BASED INSTRUCTION: EFFECT OF COGNITIVE STYLE, INSTRUCTIONAL FORMAT, AND SUBJECT-MATTER CONTENT ON LEARNING

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13. ABSTRACT *(Maximum 200 words)*

This report describes an experiment investigating the effects of cognitive style, presentation format, and task content on learning. Cognitive style was described in terms of hemisphericity (i.e., left- or right-brain influence on perception). Presentation format consisted of graphics, text, and a combination of the two. The tasks consisted of knowledge, skill, attitude and decision-making. Fifty-nine college students participated in the study. In the knowledge task, subjects learned 10 pairs of words. In the skill task, subjects built an abstract model of a windmill. In the attitude task, subjects responded to facts and opinions on a current affairs topic. The decision-making task involved a maze problem. Subjects were tested immediately after training, 2 weeks after training and again at 4 weeks after training.

Results indicated the following: Presentation format, gender, and hemisphericity all appeared to influence performance on the knowledge task. Presentation format and gender influenced performance on the skill task. Presentation format influenced performance on the decision-making task.

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This research is an initial exploration into adaptive training for computer-based systems. The ability to adapt to an individual's preferred learning style is a significant challenge for designers of training systems. The basis for the adaptability may be grounded in individual differences in cognitive style.

SUMMARY

This paper describes an experiment which attempted to identify the effects of cognitive styles, instructional format, and subject matter on learning. The following research questions were addressed: (a) Does presentation format affect performance on training tasks in the areas of knowledge, skill, attitude, and decision-making? (b) Does cognitive style affect performance on training tasks in the areas of knowledge, skill, attitude and decision-making? and (c) Does gender affect performance on the same kinds of training tasks?

For purposes of this study, cognitive styles were divided into left-brain-dominant and right-brain-dominant influences on human learning behaviors. There were four tasks in the experiment: a knowledge task which required subjects to learn facts; a skill task requiring subjects to assemble a toy windmill of abstract design; an attitude task in which subjects were required to express their opinions on a current affairs topic; and a decision-making task in which subjects had to navigate through a maze. The instructional formats used to relay instructions for the tasks included graphics, text, and text-graphics displays. Fifty-nine college students (male and female) participated in the study. Two Commodore Amiga personal computers were used. Each computer was equipped with a color Amiga monitor, two 3.5-inch disk drives and a "mouse." Video displays were developed using Deluxe Paint, Electronic Arts, and Aegis Animator software.

Research results indicated that the format of instructional material had the greatest influence on performance and that the most effective format may depend on the subject-matter content. It also appeared that gender and cognitive style may have affected performance on some tasks. A taxonomy which would combine dimensions of cognitive style, content, and mode of presentation appears valid in light of these initial results. A taxonomy of this nature could benefit training specialists and researchers in developing training methodologies and training delivery systems.

PREFACE

The present effort was supported by the Air Force Office of Scientific Research under Contract No. F49620-85-C-0013/SB5851-0360 and Subcontract No. S-760-OMG-085 with Universal Energy Systems. The study was the result of work performed by the author during a Summer Faculty Research Fellowship at the Air Force Human Resources Laboratory, Logistics and Human Factors Division, Ground Operations Branch, Wright-Patterson Air Force Base, Ohio, in 1985.

Appreciation is expressed to Dr Lawrence E. Reed and Rosemarie J. Clark for giving the author guidance concerning the needs of the Laboratory while still providing the freedom to instigate research in an area of great personal interest. Special thanks go to Kathleen Y. Moorer for administrative support and Dr Beverley Gable for helpful editorial comments.

The author also thanks Donald Sandor, a student at Wittenberg University, who was responsible for programming the experimental design, and Leslie Muehlhauser for managing the experiment. This research was conducted at Wittenberg University, Springfield, Ohio 45501.

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I. INTRODUCTION

Basic research in the areas of learning theory, memory, neuropsychology (hemisphericity), and cognitive psychology (information processing) has made significant contributions to the body of knowledge concerning how human learning occurs. This knowledge has been applied to the identification of cognitive styles. Cognitive style, initially termed such by Allport (1937), has been described as an individual's typical mode of thinking, problem-solving, perceiving, and remembering (Schwen, Bedner, & Hodson, 1979). Ausburn and Ausburn (1978) referred to cognitive style as the psychological dimensions that represent consistencies in an individual's method of acquiring and processing information.

Individual differences in cognitive style may occur in any of the mental processes used in information processing: (a) perception, (b) thought, (c) memory, (d) imagery, and (e) problem-solving. Such individual differences appear to be related to hemispheric dominance (Wittrock, 1980) and the degree to which one mode of information processing is used over another (Ausburn & Ausburn, 1978).

A number of researchers have identified various dimensions of cognitive style (e.g., Kogan, 1971; Kolb, 1976; Lowenfeld & Brittain, 1970; Messick, 1966; and Pask & Scott, 1972). See Table E-1 of Appendix E for a description of 15 dimensions of cognitive style.

Each of these dimensions represents a dichotomy and may be expressed as a bipolar relationship (Witkin, Moore, Goodenough, & Cox, 1977), with the two extremes of each relationship defined. It is imperative to emphasize that cognitive style represents a continuum within the dichotomy, and a particular individual's style tends to fall toward one or the other end of the spectrum. It is hypothesized that this dichotomy of cognitive style may also bear a relationship to the dichotomous, hierarchical functioning of the left and right hemispheres within the brain, hemisphericity. That is, many of the characteristics of left- and right-hemisphere processing described in current research appear to relate also to cognitive style dimensions.

An attempt to combine the two streams of research, cognitive styles and hemisphericity, is presented in Figure 1 (Buehner, 1987). The triangle represents a "thinking skills" hierarchy, in which thinking processes toward the top become more abstract, complex, and integrated. Characteristics of left- and right-hemispheric processing dominance are listed on the left side and right side of the triangle, respectively. As a result of study into the characteristics of each cognitive style dimension, the dichotomies of style have been matched to the characteristics of the two hemispheric processing patterns. The dimensions of conceptualization and learning behavior are proposed as having both hierarchical and lateral characteristics. The lateral characteristics become less pronounced, with hierarchical blending as higher-order thinking occurs.

Research into ways of applying this knowledge of cognitive style to the development of methodologies appropriate to computer-based instruction has

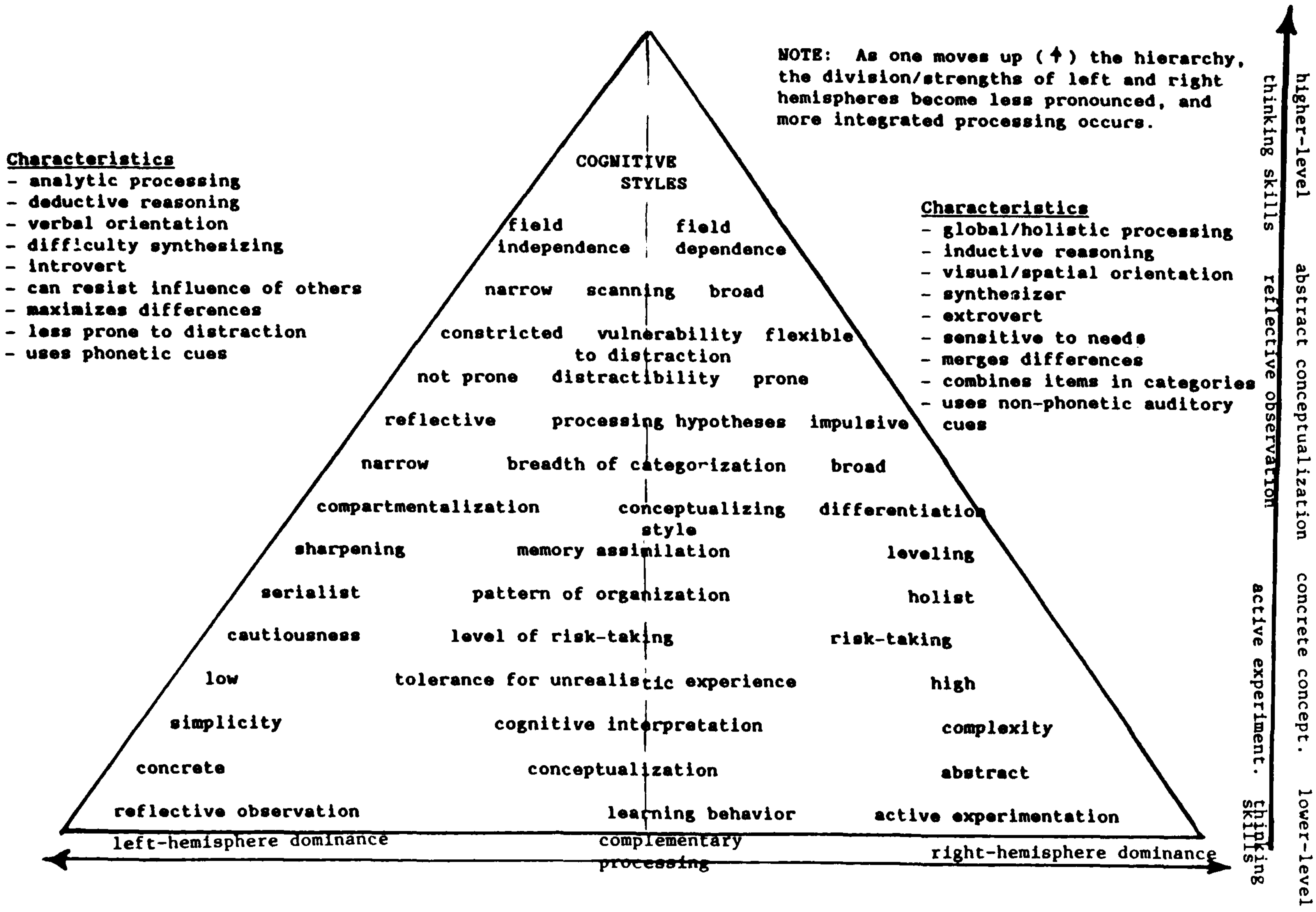

Figure 1. Style Characteristics and Thinking Skills

begun to permit more effective and cost-efficient uses of computers in a wide variety of training applications. Most instructional designers, however, are not currently provided with adequate tools and techniques for the development of instructional programs tailored to the individual needs of the trainee (learner). Therefore, many of the current training programs are designed as if all trainees process and store information in the same manner and it is the responsibility of trainees to match their learning to the format of the instruction.

Research has demonstrated that individuals process information differently (e g., Kogan, 1971; Messick, 1966). For example, some individuals best retain information presented graphically and holistically, whereas others best process information serially (with verbal presentation). Results of this research may be applied in the manner proposed in Figure 2 (Buehner, 1987), which depicts the interaction between cognitive style and instruction.

Some researchers (e.g., Moore & Nawrocki, 1978) also acknowledge the importance of taking into account the nature of the subject matter or task when planning instruction. Such considerations can facilitate retention and eventual transfer of training to the job situation.

Currently, most designers of computer-based instruction do not have adequate guidelines for the development of programs which accommodate differences both in individual cognitive style characteristics of trainees and in subject-matter content. The problem lies in the lack of adequate, detailed knowledge about the critical aspects of cognitive style and training presentation. If the elements of subject-matter content and cognitive style are consistently considered in planning instruction, training effectiveness and efficiency can assuredly be enhanced. With the development of guidelines for instructional designers, computer-based instruction shows great promise in its capacity to allow for flexibility in instruction to meet individual needs.

The objective of the present research effort was to begin to test some of the postulates described in the two figures, in conjunction with the proposed instructional design modifications described in Table E-2 (Appendix E). That is, the effort was designed to assess trainee performance when the presentation of instructional information is modified according to cognitive style and subject-matter content.

For the purposes of the present investigation, cognitive style was defined as left-hemisphere dominant and right-hemisphere dominant. Subject-matter content was divided into four areas: knowledge, skill, attitude, and decision-making. The following research questions were addressed:

1. Does presentation format affect performance on training tasks in the areas of knowledge, skill, attitude, and decision-making?

2. Does cognitive style (hemisphericity) affect performance on training tasks in the areas of knowledge, skill, attitude, and decision-making?

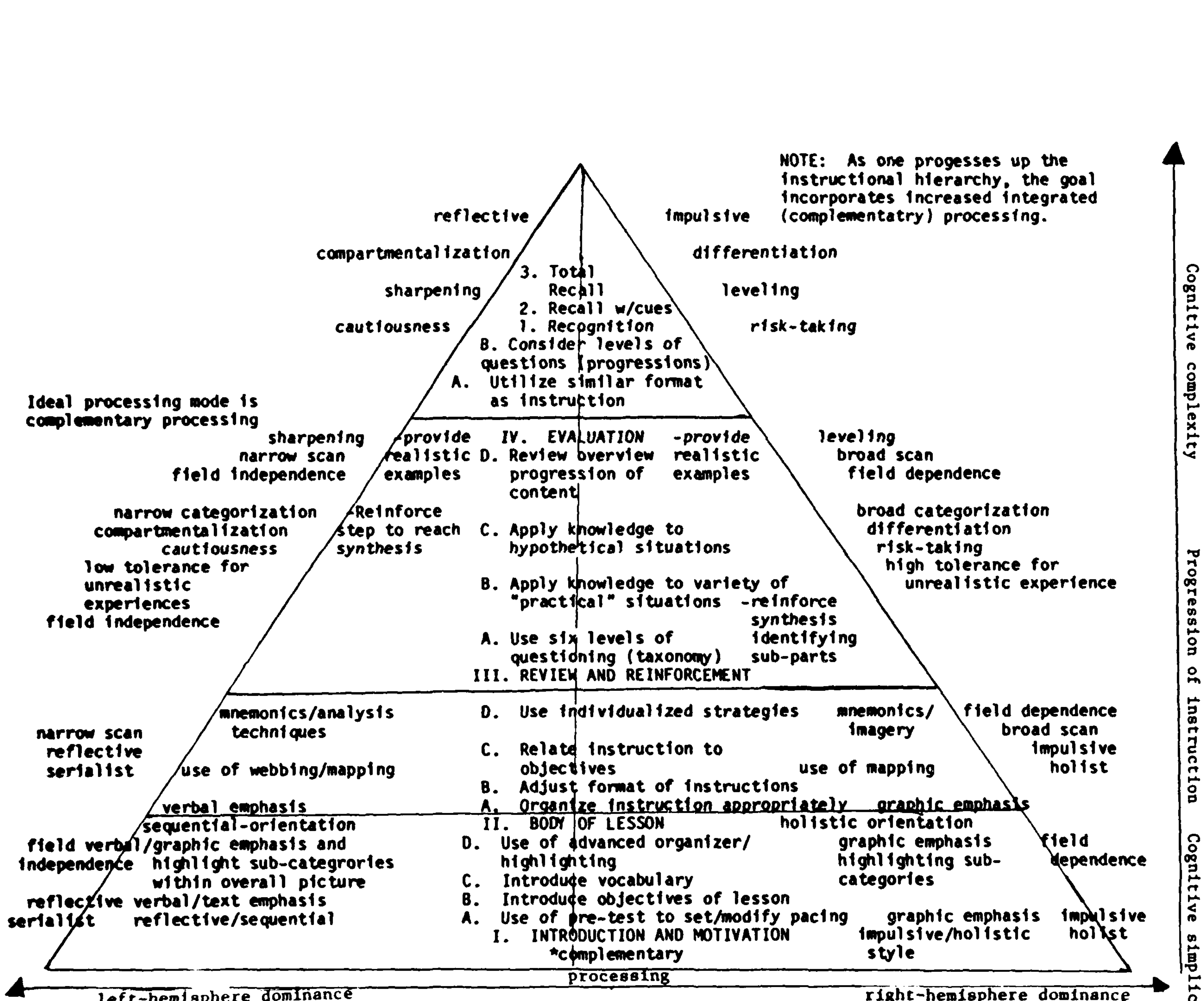

Figure 2. Style-Instruction Interaction

3. Does gender affect performance on training tasks in the areas of knowledge, skill, attitude, and decision-making? Researchers have identified gender differences related to cognitive style (see Porac & Coren, 1981).

II. METHOD

Subjects

Fifty-nine college students (29 males and 30 females) served as subjects for the study. Subjects were recruited through media advertisement, and those selected consisted only of respondents who were: (a) currently enrolled in a 2-year or 4-year college or university, and (b) between the ages of 18 and 24. The mean age of the subjects was 19.7 years. Each subject was briefly informed of the nature of the investigation. Each was told that the purpose of the study was to investigate how people learn by using computers. Demographic information was obtained. No subject was color blind. All subjects were paid for their participation.

Screening Measures for Cognitive Style

Subjects were classified according to cognitive style--either left-hemisphere dominant (n = 31) or right-hemisphere dominant (n = 28) based upon the screening measures described below. The subjects were randomly assigned to treatment conditions, with cognitive style serving as a "blocking" variable (i.e., both left- and right-hemisphere-dominant individuals were allocated to each condition).

The 4-Mat Test. McCarthy's 4-Mat Test is a self-report measure of cognitive style and hemispheric processing. The cognitive style subtest measures an individual's preference for a particular manner of perceiving information. Scores are computed to categorize four cognitive styles: (a) concrete experience, (b) abstract conceptualization, (c) active experimentation, and (d) reflective observation. These cognitive styles have been theoretically linked to hemispheric dominance (Buehner, 1987). The hemispheric processing subtest measures an individual's lateral predominance in information processing (left or right).

The Lateral Preference Test. The Lateral Preference Test (Porac & Coren, 1981) is a behaviorally validated self-report inventory designed to assess lateral preferences (see Appendix A). The instrument consists of 13 questions that ask respondents to specify which hand, foot, eye, or ear (left, right, or both) they would use to perform a specified task. Raw scores are transformed to an index on a scale of lateral preference that ranges from -1 to +1. Negative values indicate a predominance for left preference (right-dominance) and positive values indicate a predominance for right preference (left-dominance). A .91 test-retest reliability correlation has been reported for this inventory. Concurrent validity has been reported to be .90.

The Group Embedded Figures Test. The Oltman, Raskin, and Witkin's Group Embedded Figures Test is designed to measure the cognitive style dimension of field dependence/field independence (Witkin, 1965). This perceptual test requires the respondent to locate a single figure within a larger complex figure. Scores on this instrument range from 0 to 18, with higher scores indicating a more field independent cognitive style. This group instrument has obtained correlations of .63 (females) and .82 (males) when compared with Witkin's individually administered Embedded Figures Test. The reliability of this test has been reported to be .82.

The Swassing-Barbe Modality Test. For the present effort, the Swassing-Barbe Modality Test was modified to accommodate group administration. This instrument measures preference and skill for visual and auditory perception. Participants were shown a sequence of shapes, then asked to write down what they saw. These sequences became more difficult as the number of shapes in a sequence increased as the test progressed. On the second test, the participants listened as the tester read a sequence of shapes. They were then asked to write down what they heard. Scores on each subtest ranged from 0 to 45, with higher scores indicating a preference for that particular modality. The test protocol reports high face validity and a test-retest reliability of .61 for visual and .65 for auditory.

Presentation Format

The subjects in the text condition were presented information in textual format. In the graphics condition, subjects were presented the same information but in graphics form (pictures, graphs, etc.). The text-graphics condition employed a combined presentation format (i.e., the information was presented to the subject using both text and graphics).

Content Areas

Knowledge Test. The Knowledge Test was developed by the investigator to measure knowledge learned in a paired-association task for this study. The test consists of 10 pairs of words (see Appendix B), ranked from easy to hard, selected from the Weschler Paired Associate Learning Test. Reliability measures of Weschler's test are reported in the test protocol to be .80. The word list is a subroutine of a computer program that can be accessed on command by the respondent. One word at a time, from the paired list, is randomly presented to the respondent (until all pairs are presented). Respondents are required to key-in the correct match for the stimulus word. Learning on this test is measured by the number of correct responses (range 0 to 10) and errors are automatically recorded by the computer.

Skill Test. The Skill Test was designed to assess an individual's ability to build a model by following directions presented in three formats: text, graphics, and text-graphics. This test requires the individual to read a set of detailed instructions on assembling a model from a building set (Tinkertoys). The exemplar for the model resembles a windmill. The respondent is then required to identify, select, and assemble the appropriate elements from the building set as specified in the assembly instructions. The test is timed and scored (by two raters) according to the number of building set elements that are incorrectly placed. Test-retest reliability for the Skill Test is .90. A correlation of .98 was obtained for inter-rater reliability.

Attitude Test. The researcher developed this test to measure a person's attitude related to specific subject matter. The test consists of 18 true-false questions--nine which measure knowledge of fact and nine which measure attitude. The questions are presented to the respondent via computer. The order in which the questions are presented is randomized. The questions focus on the advantages of the Strategic Defense Initiative. The knowledge questions were included in the test to serve as distractors for the attitude questions. Respondents are not informed that this test is designed to measure attitude. The score range for each set of questions is 0 to 9. The test-retest reliability for this instrument is .89. (See Appendix C for an example of the questions presented.)

Decision-Making Test. This test, designed by the researcher, assesses an individual's ability to make decisions quickly and accurately. The test is a subroutine of a computer program developed for the present study. The respondent is required to progress successfully through a rectangular maze (25 steps) by following a set of rules (see Appendix D). The respondent decides which direction to move and then enters his or her choice into the computer. To prevent visual scanning of the overall maze for the solution, only a small segment of the maze is displayed to the respondent. Incorrect responses receive an audible beep and the computer displays correct choices. The number and location of errors, and the time (in seconds) to complete the maze, are recorded by the computer. The maze was pretested to determine the appropriate level of difficulty for optimal visual screen presentation.

Equipment

Two Commodore Amiga personal computers were used in this investigation. Each computer was equipped with a color Amiga monitor, two 3.5-inch disk drives, and a "mouse." Video displays required for this study were developed with the aid of the Deluxe Paint, Electronic Arts, and Aegis Animator software packages.

Two Tinkertoy Building Sets (number 220) were used during the skill testing. Each set contained building elements made of either wood or plastic. The elements came in several shapes and sizes, and in five colors, and were easily distinguishable from one another. A stopwatch (measuring to thousandths of a second) was used to time the skill testing.

The study was conducted at Wittenberg University in the Department of Education Building. Two rooms were used to conduct all the training and testing sessions. Each room contained a desk (which held the computer equipment), two chairs, and all the equipment necessary for conducting the session. The rooms were free of outside noise and distractions.

Procedures

This study employed a 2 X 2 X 3 X 3 (Gender X Cognitive Style X Presentation Format X Time) factorial design for the knowledge, skill, and decision-making content areas. Performance measures were obtained immediately following training, and at 2 weeks and 4 weeks after training was completed

(Time). For the attitude content areas, a 2 X 2 X 3 X 4 (Gender X Cognitive Style X Presentation Format X Time) design was employed. Measures for the attitude content area were taken at pre-training (Time 1), post-training (Time 2), and at 2 weeks (Time 3) and 4 weeks (Time 4) following training.

Cognitive Style Assessment

The 4-Mat Test, Group Embedded Figures Test, and the Swassing-Barbe Modality Test were used to categorize subjects by cognitive style. The Lateral Preference Inventory was used to group subjects according to hemispheric dominance. Subjects with scores from -1.00 to +.23 were judged right-hemisphere dominant (n = 28), and those with scores of +.38 to +1.00 were judged left-hemisphere dominant (n = 31). Subjects were blocked according to cognitive style (left- and right-hemispheric dominance) and randomly assigned to one of three presentation format treatment conditions (text, n = 20; graphics, n = 20; text-graphics, n = 19) such that there were both left- and right-hemispheric-dominant subjects in each treatment condition. Subjects were not informed during the study that there were three presentation format conditions.

Training

Subjects received training in the content areas: knowledge, skill, attitude and decision-making. The order was counterbalanced. The order of format presentation (text, graphics, and text-graphics) was also counterbalanced for all subjects to control for order-of-presentation effects.

Knowledge Training. The knowledge training required subjects to learn 10 pairs of words. Subjects in the text condition were presented with a word pair and a sentence containing both words. The word-pair/sentence presentation was employed to increase the potential for mnemonic memory. Only one word pair/sentence appeared on the screen at each presentation in order to minimize distraction and visual confusion. The time interval of each presentation was fixed, and advancement to the next word-pair/sentence presentation was automatic, thus ensuring that presentation intervals were constant across subjects. Subjects practiced the word list once. Subjects keyed-in their response to the stimulus word presented on the video screen. The correct response was acknowledged by the computer by displaying the word "correct" on the screen and presenting the next stimulus word in the list. If the response was incorrect, the computer displayed the correct word, along with the sentence containing that particular word pair.

In the graphics condition, the training was identical to the training in the text condition except that pictures rather than text were used to communicate the meaning of the sentences. Subjects in the text-graphics condition also followed the same procedure (as in the text condition), except that the sentences and the pictures were presented on the video screen with the paired words.

Skill Training. In the skill training, subjects were required to build a windmill from Tinkertoys. In the text condition, subjects were given time to read three pages of written directions for building the windmill. The directions were presented one page at a time, with a time limit for each page. After reviewing these directions, all subjects were given the first page of directions and the pieces necessary for building the windmill (plus five distractor pieces), and were told to build the windmill as quickly as possible. After completing this page, they were given the second page and received the third page after completing the second. In each case, they could not return to a previous page.

In the graphics condition, subjects were shown three consecutive computer-generated pictures, corresponding to each of the three pages of text. The same procedure was followed for this condition, with the subjects using only the pictures to build the windmill.

In the text-graphics condition, subjects were given both the pictures and the written directions to complete the task.

Attitude Training. In the attitude training, subjects were first asked to complete a pre-test. The training emphasized the advantages of the continuance of the Strategic Defense Initiative (SDI) project. In the text condition, subjects read five screen "pages" of text (which were timed to advance automatically) describing the benefits of SDI. Subjects then completed a post-test consisting of questions based upon the reading.

Subjects in the graphics condition were shown five pictorial graphs (describing the same information given in the text condition). In the text-graphics condition, subjects were shown both the text and the graphics.

Decision-Making Training. In the decision-making training, subjects were given three rules necessary to successfully complete a maze. In the text condition, the rules were presented individually on the screen, with timed advancement to the next rule. In the graphics condition, the rules were presented in pictures. In the text-graphics condition, subjects were presented with both the written rules and the pictures. Subjects were permitted to practice moving through a maze, with the rules on the screen at all times. Feedback was given to each subject, and errors were identified.

Performance Testing

Subjects were tested for performance in each content area immediately following the training interval. Subjects also were tested at 2-week and 4-week intervals following training, to measure retention. Subjects were tested two at a time in separate rooms.

For each testing session, the order of presentation of the four content areas (knowledge, skill, attitude, and decision-making) was randomized for each subject, and the order of presentation for questions on the attitude and knowledge measures was also randomized.

III. RESULTS

Presentation Format

A one-way analysis of variance was performed for each of the four content areas. Results indicated statistically significant differences among groups receiving text, graphics, or text-graphics on the skill test and the decision-making test.

Analyses were performed to indicate significant differences among groups receiving text, graphics, or text-graphics at each testing time for each content area. The results are discussed below.

Knowledge Test. The results of the knowledge test indicated no significant differences among the presentation format groups. The knowledge test at Time 1 indicated a higher number of errors for the text condition than for the graphics or text-graphics condition (see Table E-3, Appendix E), but these differences were not significant at the .05 level.

Skill Test. At Time 1, a significant difference between groups was obtained on the number of seconds to complete the skill test, F (2,58) = 9.30, $p < .001$. A Newman-Keuls analysis on these differences indicated that subjects in the graphics condition and the text-graphics condition took less time to complete the task than did subjects in the text condition (see Table E-4, Appendix E).

At Time 2, the difference between groups was again significant, F (2,58) = 4.33, $p < .02$. Again, analyses indicated that subjects in the graphics condition and the text-graphics condition took less time to complete the task than did subjects in the text condition.

At Time 3, the difference between groups was significant, F (2,58) = 3.56, $p < .03$, and the subjects in the graphics condition took less time to complete the task than did subjects in the text condition and the text-graphics condition.

Additionally, on the skill test at Time 2, a significant difference between groups was obtained on the number of errors, F (2,58) = 3.95, $p < .05$, with the subjects in the graphics condition having more errors than did those in the other two groups. This difference was also significant at Time 3, F (2,58) = 9.19, $p < .001$, and the graphics condition again had more errors than did the text or the text-graphics condition.

Attitude Test. The results of the attitude test indicated no significant differences among groups.

Decision-Making Test. On the decision-making test, the groups did not significantly differ as to the number of seconds required to complete the task. At Time 1, however, a significant difference between groups was obtained on the number of errors, F (2,55) = 5.83, $p < .01$. The subjects in the graphics condition had more errors than did those in the other two groups (see Table E-5, Appendix E). Table E-4 indicates that those in the text-graphics condition maintained fewer errors from Time 1 through Time 3 than did those in the other two conditions.

Gender Data

Analyses for gender differences in each presentation format condition for the four content areas were performed.

Knowledge Test. At Times 1 and 2 of the knowledge test, significant differences were obtained (see Table E-6, Appendix E), with $F(1,19) = 4.11$, $p < .04$ at Time 1, and $F(1,19) = 4.39$, $p < .05$ at Time 2. At both Time 1 and Time 2, in the text condition, males made fewer errors than females did on the knowledge test.

Skill Test. No significant gender differences were found for this test.

Attitude Test. In the text condition, significant differences were noted at Times 2 through 4 on the attitude test (see Table E-7, Appendix E), with males making fewer errors than females on this test at Time 2, $F(1,19) = 5.79$, $p < .03$; at Time 3, $F(1,19) = 4.97$, $p < .04$; and at Time 4, $F(1,19) = 6.00$, $p < .02$.

Decision-Making. The number of errors on the decision-making test at Time 2 resulted in a significant difference between groups, $F(1,18) = 5.60$, $p < .03$. Males ($M = 4.8$) had fewer errors on this task than did females ($M = 9.3$).

Cognitive Style (Hemisphericity)

Effects of hemisphericity on performance were studied for each of the three presentation format conditions. No significant differences were obtained among groups in the text format condition.

In the graphics format condition on the knowledge test, at Time 2, the difference between groups was significant, $F(1,19) = 4.55$, $p < .05$ (see Table E-8, Appendix E). Left-dominant subjects had fewer errors on this test than did right-dominant individuals. The difference between groups at Time 3 was also significant, $F(1,19) = 6.22$, $p < .02$. Left-dominant subjects again had fewer errors than did right-dominant subjects. No other differences on the knowledge test were significant.

In the text-graphics format condition, the difference between groups at Time 1 on the attitude test was significant, $F(1,17) = 9.33$, $p < .01$. Right-dominant subjects ($M = 4.2$, $n = 9$) had fewer errors ($M = 4.2$) than did left-dominant subjects ($M = 7.5$, $n = 11$,). No other results regarding hemisphericity were statistically significant.

Hemisphericity-by-Gender Data

On the skill test, at Time 3, an interaction effect of hemisphericity by gender was obtained, $F(1,50) = 5.62$, $p < .02$. Further analysis indicated that, for right-hemisphere-dominant subjects, a significant difference between the performances of males and females was obtained, $F(1,27) = 6.52$, $p < .01$. Females ($M = 279$, $n = 15$) had shorter completion times than males ($M = 347$, $n = 13$) on this task.

IV. DISCUSSION

Presentation Format

Does presentation format affect performance on training tasks in the areas of knowledge, skill, attitudes, and decision-making? The results support the notion that presentation format affects performance on tasks in varying content areas. The two content areas showing significant differences were the skill task and the decision-making task. The remaining two content areas, knowledge and attitude, did not produce significant results. However, the data demonstrate trends toward format preference, and may warrant further research.

Skill Test. For the skill task specifically, results indicate that subjects in the graphics format condition had shorter completion times than those in the other two conditions. Those in the text format condition demonstrated the slowest times in completing the task. Therefore, on tasks of this nature, where the goal is fast completion of a skill, the graphics format may be the most appropriate format for presenting information. It may also be that the text-graphics format may actually confuse some individuals by giving too much information and dividing attention between the textual and pictorial information presented.

With regard to accuracy in the skill task, however, subjects in the graphics condition made significantly more errors than did subjects in the other two groups. Those in the text-graphics condition had the fewest number of errors.

In computer-based training of a skill, when both speed and accuracy are important, it appears that the text-graphics format may be the most appropriate. A speed-accuracy tradeoff was indicated by the results. Trainers may wish to sacrifice some speed to gain accuracy. Future training research should focus on the appropriate amount of textual and graphics information available on the screen simultaneously for optimal performance. In much of the training of skills for military personnel, both speed and accuracy are equally important. Therefore, attention to the appropriate configuration of text and graphics for simultaneous presentation is important to training of skills for military personnel.

Decision-Making Test. In the decision-making content area, subjects in the graphics format had more errors after initial training than did those in either the text or the text-graphics condition. This difference decreased over time. Although this was a simple decision-making task, it was designed to exemplify sequential decision-making at a three-step level. A graphics format may not be the most effective when teaching procedural decision-making tasks.

Gender

Does gender affect performance in the four content areas? Males outperformed females on the knowledge task. This result supports the research on gender differences for analytical and knowledge-based tasks (Porac & Coren, 1981). This difference may suggest a change in training approaches for males and females when teaching analytical, knowledge-based information. For males, presentation format made little difference in their performance in relation to females. The performance of males was highest in the graphics presentation format.

Females, although consistently scoring below males, performed the highest in the text condition. Further research in this area could focus on gender differences in performance of knowledge-based tasks, with the possibility that appropriate presentation formats for training may vary with males and females. For males, a graphics format may be the most effective, whereas a text format may be more effective for females.

Cognitive Style (Hemisphericity)

Does hemisphericity affect performance in the four content areas? Differences attributable to hemisphericity occurred on both the knowledge task and the attitude task.

Knowledge Test. On the knowledge task, the differences were most evident in the graphics condition. Left-dominant subjects made fewer errors than right-dominant subjects when given information in the graphics format. In addition, left-dominant subjects in the graphics condition outperformed left-dominant subjects in the text and text-graphics conditions. Right-dominant subjects in the text-graphics condition had the lowest number of errors of all right-dominant subjects.

The results may lend initial support for the training of knowledge-based information in a graphics format for those who are left-dominant. Right-dominant individuals may benefit from information presented in a text-graphics format. Overall, left-dominant individuals performed slightly better on the knowledge task than did right-dominant individuals. This finding supports prior evidence as to the location of hemispheric processing of knowledge-based information (Porac & Coren, 1981). Left-hemisphere processing has been demonstrated to play a primary role in language, and a major role in reading and in the learning of knowledge-related tasks (e.g., Hart, 1983; Hermann, 1981; Kinsbourne, 1978). These results suggest that left-dominant individuals may perform better on tasks of this nature, regardless of presentation format.

Attitude Test. Before training in attitudes, right-dominant individuals made fewer errors on the attitude test than did the left-dominant individuals. In addition, over time, right-dominant individuals changed attitudes more than did left-dominant subjects, and maintained the attitude change over a longer period of time when given information in the text-graphics format. This result supports research findings in the area of information processing of attitudinal information (Hart, 1983; Hermann, 1981; Porac & Coren, 1981). For left-dominant subjects, the lowest number of errors occurred in the graphics format.

The implication from the results on hemisphericity is that some modification of training programs on attitude and knowledge-based information is in order. Future research could focus on the degree to which modification is necessary in these two content areas. Additional research could focus on the appropriate learning environment for right-dominant individuals in order to enhance their performance in relation to left-dominant persons.

Conclusions

Of those factors studied in the present investigation, it appears that the format of instructional material has the greatest influence on performance, and that the most effective format may depend on the content (knowledge, skill, attitude, or decision-making). It appears that gender and cognitive style may also affect performance on some tasks. Thus, the aspect of the taxonomy dealing with content variations appears to have initial support in the results of this research.

Future research can focus on continued testing of this taxonomy, setting a goal toward developing, for instructional designers, guidelines appropriate to the relevant aspects of content and trainee cognitive styles.

Limitations

Several limitations to this study appear relevant:

1. Although subjects were randomly assigned to presentation format conditions, they were not randomly drawn from the population. The subjects for this study were all college students. In military training, especially for entry-level personnel, this may not be the case. Therefore, these results can be generalized only to other populations of similar age and educational levels. The results, however, do merit further consideration as promising possibilities in the design of effective computer adaptive training.

2. The assessment device used to categorize subjects into left- and right-hemisphere dominance may have not been the most appropriate. Correlational data may lend support to additional aspects and measures of cognitive style more relevant to training in the four content areas. Although the measure of cognitive style used for blocking subjects has validity and reliability data available, research in this area is still in its early stages. It remains to be determined whether hand, foot, and eye preferences also relate to the preferences for the cognitive processing of information as measured in the knowledge, skill, attitude, and decision-making tasks. Preliminary data from this research, however, appear to support the theoretical and empirical perspectives on cognitive style effects in information processing.

In addition, depending on the types of subjects available, the persons classified as *right-dominant may or may not* score between -1 and 0 on the Lateral Preference Test (Porac & Coren, 1981). Since right-dominant persons appear to be in the minority (Wittrock, 1980), a larger sample would have been needed in order to have a right-dominant group who scored within this range. Therefore, subjects classified as right-dominant for the purposes of this study scored between -1 and +.23 on this instrument, and may have tended toward more integrative processing. For this reason, some cognitive style effects might have been more evident, as in the skill task, had scores of -1 to 0 (right-dominant) and 0 to +1 (left-dominant) been used for the blocking of subjects for this study. There was, however, a substantial difference between the highest score for the right-dominant subjects (+.23) and the beginning score for the left-dominant subjects (+.38). In addition, the mean for left-hemisphere-dominant individuals was +.82, while the mean for right-hemisphere-dominant individuals was -.20. This classification should, therefore, be considered appropriate for these circumstances.

3. A practice effect may have altered performance data on the decision-making task, as subjects completed the same maze at all three testing sessions.

4. The training was designed to simulate tasks representative of actual training tasks in the content areas of knowledge, skill, attitude, and decision-making. These training tasks were succinct and measured only one example of tasks in these areas. Therefore, this research is only the beginning of investigations into computer adaptive training.

Follow-On Research

Follow-on research can take several directions. First, research should continue efforts related to identified dimensions of cognitive style. Research into the nature of these characteristics and their relevance to adaptive training models should be conducted.

Second, research should focus on the development of a computer-based assessment instrument useful at the onset of a training task. This instrument could assess the most salient factors for effective performance in training tasks in the content areas of knowledge, skill, attitude, and decision-making. The present research has identified several possible factors important to consider in the development of training programs (presentation format, cognitive style, and gender). Observational data indicate that many of the computer-based military training programs can be categorized into one of the four content areas identified for this research project. With additional research, it may be possible to develop either a cross-content or content-dependent instrument to assess trainee characteristics before training. Since computer-based training offers opportunities for the development of adaptive training programs, these programs could then be adapted to meet individual training needs.

Finally, research should continue testing the proposed taxonomy, which later may be employed in the development of guidelines for designers of computer-based training programs.

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APPENDIX A

Lateral Preference Test

Directions: Please circle the response that represents the hand, foot, eye, or ear you would use in most cases. Circle "both" if you would usually use each equally as well.

	Left	Right	Both
1. With which hand would you throw a ball to hit a target?	L	R	B
2. With which hand do you draw?	L	R	B
3. With which hand do you use an eraser on paper?	L	R	B
4. With which hand do you give out the top card when dealing?	L	R	B
5. With which foot do you kick a ball?	L	R	B
6. If you wanted to pick up a pebble with your toes, which foot would you use?	L	R	B
7. If you had to step up onto a chair, which foot would you place on the chair first?	L	R	B
8. Which eye would you use to peep through a keyhole?	L	R	B
9. If you had to look into a dark bottle to see how full it was, which eye would you use?	L	R	B
10. Which eye would you use to sight down a rifle?	L	R	B
11. If you wanted to listen in on a conversation going on behind a closed door, which ear would you place against the door?	L	R	B
12. If you wanted to hear someone's heart beat, which ear would you place against their chest?	L	R	B
13. Into which ear would you place the earphone of a transistor radio?	L	R	B

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APPENDIX B

Word Pairs for Knowledge Task

1. Come - Go
2. Lead - Pencil
3. In - Although
4. Country - France
5. Dig - Guilty
6. Lock - Door
7. Jury - Eagle
8. Murder - Crime
9. Knife - Sharp
10. Necktie - Cracker

APPENDIX C

ATTITUDE TEST QUESTIONS

Directions: Read each of the following true/false questions. If the statement is false, write "F." If the statememt is true, write "T." Here are the questions.

1. ______ Because of the SALT I Treaty, the Soviet Union has discontinued the building of military resources.

2. ______ Since the Strategic Defense Initiative (SDI) can intercept missiles launched from submarines, it is important for the United States to protect its major coastal ports and cities by continuing this program.

3. ______ The United States is not as strong in military force for defense as is the Soviet Union.

4. ______ The United States is at an advantage in the number of intermediate and intercontinental missiles.

5. ______ The greatest threat to the United States from the Soviet Union is in the balance of aircraft between the two countries.

6. ______ The Soviet Union has produced significantly less submarines, aircraft and armor in the years 1974-1982 than the United States.

7. ______ The SDI program President Reagan proposes is designed to be the most effective defense against submarine attacks.

8. ______ The United States has not remained within the limits of the SALT I Treaty.

9. ______ The United States needs to spend money to build military forces to become more equal to the Soviets.

10. ______ Since the major concern of the United States is to protect the lives of innocent people in times of war, the SDI (with its accuracy in hitting only targets) would provide necessary protection for United States citizens.

11. ______ If the Soviets are not remaining within the limits of SALT I, it is important for the United States to increase money spent on defense.

12. ______ Due to the imbalance of aircraft between the two countries, it is advantageous for the United States to continue its development of the SDI program.

APPENDIX C (Concluded)

13. ______ The Soviet Union has broken a promise made in the SALT I Treaty by continuing to build military strength.

14. ______ If an enemy were to conduct a nuclear attack on the city of Chicago without an effective United States defense such as SDI, a relatively few number of people would die instantly.

15. ______ If we were to go to war with a nation such as the Soviet Union, the United States may lose because of an imbalance of weapons support.

16. ______ The development of SDI can act to equalize the balance of arms buildup between the two world powers.

17. ______ The United States should have an equal number of weapons as the Soviet Union to insure peace, not war.

18. ______ In the years 1974-1982, the Government Union produced less of both aircraft and armor than the United States.

APPENDIX D

Rules for Decision-Making Task

1. If a door is open directly in front of you, go through it.

2. The left and right turns that you will make develop into a pattern or sequence. Look for that pattern and make your decision based on it.

3. After a Left/Right sequence repeats itself three times, it will reverse itself (i.e., Left turns will become Right turns and Right turns will become Left turns).

APPENDIX E

TABLES

TABLE E-1. Fifteen Dimensions of Cognitive Style

1. Field-independence Versus Field-dependence (Witkin, 1965)

Individual differences as to the manner in which individuals perceive themselves in spatial terms. Field-independent individuals perceive analytically and can easily separate "figure" from "ground." Field-dependent individuals perceive globally and have difficulty organizing/separating simple from more complex figures.

2. Reflective Versus Impulsive (Kagan, 1965)

Individual differences regarding the speed and manner in which hypotheses are selected and processed. Reflective individuals delay a long period of time before acknowledging a solution. Impulsive individuals select the first solution and are, as a result, many times, incorrect.

3. Sharpening Versus Leveling (Holzman, 1952; Klein & Schlesinger, 1951)

Consistent individual variations in memory assimilation (in the identification and integration of impressions). Sharpening reflects a tendency to maximize perceived differences and is less prone to confusion of similar stimuli. Leveling individuals minimize perceived differences and merge past memories.

4. Breadth of Categorizing (Kogan, 1971; Pettigrew, 1958)

Individual differences as to the degree to which an individual will include items within categories. Individuals with narrow categorization styles are resistant to the inclusion of many items in a single category. Individuals with a broad style demonstrate a willingness to include many items within one category.

5. Scanning (Messick, 1970)

Individual differences in attention deployment which produce variations in vividness of experience and range of awareness. Differences may be described in terms of narrow or broad deployment of attention.

6. Tolerance for Unrealistic Experiences (Klein & Schlesinger, 1951)

Individual differences (demonstrated in research studies on apparent movement) as to willingness to accept perceptions which vary from experience. A less tolerant individual style is more bound to reality and has a more restricted range of illusionary movement. A more tolerant style allows for a broader range.

TABLE E-1 (Continued)

7. Cognitive Complexity-Simplicity (Kelly, 1955)

Individual differences in the tendency to interpret the world in a complex, multidimensional way. This includes the number of dimensions and individual forms in judgments or the number of discriminations within constructs. Current research reviews the continuum of abstractness/ concreteness.

8. Conceptualizing Styles (Messick & Kogan, 1963)

Individual differences in the way individuals approach the categorization of similarities/differences among stimuli. This includes two aspects: equivalence range (very similar to breadth of categorization) and conceptual differentiation (differentiation-compartmentalization). Differentiation is the number of groups to which more than a single item is assigned. Differentiation correlates with verbal knowledge and vocabulary level (synthesis of information). Compartmentalization indicates the number of single items not placed in any categorical group. Compartmentalization correlates negatively with creativity and demonstrates difficulty in generating alternate conceptual schemes.

9. Constricted Versus Flexible Control (Gardner, Holzman, Klein, Linton & Spence, 1959)

Individual differences in individuals' vulnerability to cognitive and environmental distraction. A constricted style represents retention of incidental stimulation and a flexible style indicates failure of retention. Kogan (1971) questions this interpretation of terminology. For these purposes, the terms will be reversed.

10. Distractibility (Santostefano, 1969)

The degree to which individuals react to contradictory cues. This is an outgrowth of constricted versus flexible control which has been related to (but is different from) field-dependence/field-independence. This style implies a range of individual proneness to distraction. This aspect of cognitive style has not been researched as thoroughly as others.

11. Visual Versus Haptic (Lowenfeld & Brittain, 1970)

The degree to which individuals rely on visual or kinesthetic cues for information processing. The visual individual uses visual imagery, holistic processing, and the integration/synthesis of component parts. The haptic individual uses "bodily" perceptions, and is kinesthetically oriented. An "indefinite" individual combines the use of both.

12. Cautiousness Versus Risk-Taking (Kogan, 1971)

Individual differences in willingness to take risks in decision-making situations. Although this dimension is usually task-specific, there are some

TABLE E-1 (Concluded)

individuals who consistently perform at either cautious or risk-taking levels. Other individuals tend to react according to task.

13. Concrete Versus Abstract Conceptualization (Kolb, 1976)

The degree of abstractness individuals utilize in conceptualizing information. A concrete conceptualizer uses concrete experiences; an abstract conceptualizer utilizes abstractions to conceptualize information.

14. Active Experimentation Versus Reflective Observation (Kolb, 1976)

The degree of involvement preferred by individuals when learning a concept. Active experimentation refers to an active, "hands-on" style in learning as opposed to a more reflective, "thought-oriented" style.

15. Serialist Versus Holist (Pask & Scott, 1972)

Individual differences as to the manner in which individuals prefer to input information. A serialist follows a deductive, analytical approach, with the preferred presentation sequence organized in a step-by-step, developmental format. A holist prefers to view the more global elements of information initially, then support these elements with sequential detailing.

Table E-2. Cognitive Styles and Possible Instructional Modifications

1.	Field-Independence	Field-Dependence
	- use advanced organizer to define advanced relationships - use highlighting - review to synthesize information	- use advanced organizer - use highlighting - review to direct synthesis of information
2.	Reflective	Impulsive
	- adjust the pacing on instruction - highlight points of emphasis during instruction	- adjust the pacing of instruction to "slow down" for effective performance - highlight points of emphasis during instruction
3.	Sharpening	Leveling
	- demonstrate relationships through use of a "web" - use mnemonics to combine characteristics - utilize all levels of questioning to force combination of training components	- highlight differences - use mnemonics to direct combinations - use variety of questioning techniques to focus and direct attention
4.	Narrow Categorization	Broad Categorization
	- use "webs" to structure information - use advanced organizers to provide overview of training - use frequent review and reinforcement to combine training components	- use webbing to structure information - use advanced organizers to focus attention on important aspects of training program - use highlighting to direct attention

Table E-2. (Continued)

5. <u>Narrow Scanning</u> - spread spacing on page and use highlighting - use graphic symbols as keys to direct attention - display information at different times to clearly direct attention	<u>Broad Scanning</u> - focus attention with use of highlighting - use graphic symbols as keys to focus attention - display information at different times to clearly direct attention
6. <u>Low Tolerance for Unrealistic Experiences</u> - use realistic examples (visual and verbal) - use a variety of examples for application of concepts - use actual materials whenever possible	<u>High Tolerance for Unrealistic Experiences</u> - use realistic examples (visual and verbal) - use a variety of examples for application of concepts - utilize color and graphics to enhance interest
7. <u>Cognitive Simplicity</u> - use highlighting to narrow field of vision - use outline/mapping to organize information - arrange information well-spaced on screen (minimize "clutter")	<u>Cognitive Complexity</u> - provide graphic organizer (cognitive map) to organize - utilize realistic examples to apply training to variety of situations - use mnemonics to combine and classify information

Table E-2. (Continued)

8.	Compartmentalization - use webbing/mapping - choose experiences forcing the combination of categorization - use variety of questioning techniques and feedback to encourage the identification of interrelationships among training components	Differentiation - use webbing/mapping - use highlighting to classify appropriate information - provide realistic examples demonstrating application of training information
9.	Constricted - use highlighting to emphasize - use different sizes of lettering, etc. to stress organization of information - add additional information progressively	Flexible - use highlighting to narrow focus of attention to important training components - utilize graphics and color to provide interest and examples of information presented - provide frequent opportunities to review/reinforce information presented
10.	Not Prone to Distraction - arrange information on screen for best retention of greatest possible amount of information - allow trainee flexibility to determine amount of feedback and review - use graphics and color to vary presentation mode	Prone to Distraction - limit amount of information displayed at a given time - use highlighting to direct attention - provide frequent feedback and reinforcement - provide frequent review using colors and graphics

Table E-2. (Continued)

11.	<u>Visual</u> - use color and graphics to reinforce ideas - provide realistic experiences to provide opportunities to apply training - provide outline for organization of training	<u>Haptic</u> - use color and graphics to reinforce concepts - provide experiences in working with equipment, etc. (i.e., "hands-on" training) - provide realistic examples to assist trainee in applying information presented
12.	<u>Cautiousness</u> - use directed learning experiences - provide experiences for aided generalizations - provide experiences which become sequentially more complex	<u>Risk-Taking</u> - use directed learning experiences to control amount of information and direct attention - use highlighting to focus attention on appropriate information - provide experiences which become sequentially more complex
13.	<u>Concrete Conceptualization</u> - begin with concrete experience and move toward abstract - use mnemonics to combine and categorize training content - use webbing to show relationships among training components	<u>Abstract Conceptualization</u> - begin with concrete experiences, allowing flexibility for holistic processing - provide realistic experiences to apply knowledge gained - provide opportunities for frequent review and reinforcement

Table E-2. (Concluded)

14.	<u>Active Experimentation</u> - provide opportunities applying information to realistic situations - give realistic examples throughout training program - provide frequent review and reinforcement to apply knowledge	<u>Reflective Observation</u> - allow flexibility in pacing presentation - allow flexibility for reviewing information presented - provide realistic examples of applications of information presented
15.	<u>Serialist</u> - provide learning experiences in sequential manner - gradually induce holistic processing - use questioning to force both sequential and holistic processing	<u>Holist</u> - introduce information holistically - force sequential development of concepts within a holistic framework - use questioning to force both sequential and holistic processing

Table E-3. Mean Number of Errors on the Knowledge Test in Three Presentation Format Conditions

Format	n	Time 1	Time 2	Time 3
Text	20			
M		1.00	5.00	5.20
SD		1.21	1.73	1.96
Graphics	20			
M		.25	5.05	5.30
SD		.72	1.50	1.69
Text/Graphics	19			
M		.58	4.47	4.74
SD		1.07	2.29	2.31

Table E-4. Mean Number of Seconds to Complete Skills Test in Three Presentation Formats Across Time

Format	n	Time 1	Time 2	Time 3
Text	20			
M		*740.80	*433.50	*335.30
SD		263.48	83.28	60.23
Graphics	20			
M		441.30	329.80	272.20
SD		162.62	89.71	76.40
Text/Graphics	19			
M		573.05	381.00	*323.47
SD		222.66	150.90	97.88

* statistically significant.
M = mean.
SD = standard deviation.

Table E-5. Mean Number of Errors on the Decision-Making Test in Three Presentation Format Conditions

Format	n	Time 1	Time 2	Time 3
Text	20			
M		3.2	1.6	1.2
SD		4.0	1.8	1.4
Graphics	20			
M		*3.6	2.9	3.3
SD		1.9	1.8	2.2
Text/Graphics	19			
M		1.8	1.5	1.1
SD		2.0	1.6	1.6

* statistically significant.

Table E-6. Mean Number of Errors for Knowledge Test in the Text Presentation Format Condition by Sex

	n	Time 1	Time 2	Time 3
Males	8			
M		* .4	*4.0	4.5
SD		.5	1.3	2.0
Females	12			
M		1.4	5.5	5.6
SD		1.4	1.7	1.9

* statistically significant.

Table E-7. Mean Number of Errors on the Attitude Test in the Text Presentation Format Condition by Sex

	n	Time 1	Time 2	Time 3	Time 4
Males	8				
M		5.2	*.9	*.4	*.5
SD		3.2	.6	.7	.5
Females	12				
M		5.0	2.1	2.6	2.4
SD		3.5	1.3	2.7	2.1

* statistically significant.

Table E-8. Mean Number of Errors for Knowledge Test in the Graphics Presentation Format Condition by Hemisphericity

	n	Time 1	Time 2	Time 3
Left-Dominant	11			
M		.4	*4.4	*4.5
SD		.9	1.7	1.7
Right-Dominant	9			
M		.1	5.8	6.2
SD		.3	.8	1.1

* statistically significant.

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