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Analogical Processing Skills in Three Modalities in Fifth, Eighth, and Eleventh Graders

Amy Sirrae Cashen
Western Michigan University

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**ANALOGICAL PROCESSING SKILLS IN THREE MODALITIES
IN FIFTH, EIGHTH, AND ELEVENTH GRADERS**

by

Amy Sirrae Cashen

**A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Speech Pathology
and Audiology**

**Western Michigan University
Kalamazoo, Michigan
December 1989**

**ANALOGICAL PROCESSING SKILLS IN THREE MODALITIES
IN FIFTH, EIGHTH, AND ELEVENTH GRADERS**

Amy Sirrae Cashen, M.A.

Western Michigan University

This study examined the ability of fifth, eighth, and eleventh graders to complete multiple modality analogy tasks. Three groups, for a total of 201 subjects--68 fifth graders, 66 eighth graders, and 77 eleventh graders--solved word, picture, and figure analogies. A significant difference was found in the performance of the three groups, indicating that analogical processing skills increase with age. No significant difference was found between males and females on the combined analogy tasks. A significant difference was found for modality, indicating that the three sets of analogies were different in difficulty. The grade-by-modality interaction also was found to be significant, revealing that the difficulty of the three analogy tasks was experienced differentially by the grades. Post hoc analysis determined that the differences between word and picture analogies, word and figure analogies, and picture and figure analogies were significant over all grades.

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Amy Sirrae Cashen

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Cashen, Amy Sirrae, M.A.

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CHAPTER I

INTRODUCTION

Analogical Reasoning as a Measure of Intelligence

Analogical reasoning has long been recognized as bearing a close relationship to human intelligence (Sternberg, 1977a; Spearman, 1927). In fact, analogies have played an important role in the various theories of human intelligence (Sternberg, 1977a; Guilford, 1967; Spearman, 1927). Spearman (1927) suggested that if analogy tests were properly made and used, then they correlated with the "g factor," his general factor of intelligence. Guilford (1967) stated in his Structure of Intellect model that "...one of the best types of CFR [cognition of figural relations] is a figure-analogies form" (p. 86). Figural analogies utilize geometric figures in a typical analogy problem. He also found analogies to be a good indicator of CBR [cognition of behavioral relations]. Many ability tests use analogies, including the Miller Analogies Test, the Scholastic Aptitude Test, and the Graduate Record Examination (Sternberg, 1977a).

Analogical Reasoning and Problem Solving

Analogical thinking is pervasive in everyday life situations (Holyoak, Junn, Billmann, 1984; Sternberg,

1977a, 1977b; Sternberg & Nigro, 1980). Humans reason analogically when solving novel problems by relating them to past situations (Holyoak et al., 1984). For instance, Sternberg (1977a) provided the example of a person listening to a friend's advice because it was correct in an earlier similar experience, or of a person buying a new goldfish because he liked the old one. In both situations, analogical reasoning is used. Spearman (1927) offered the view that "by analogy with his own inner experience a person proceeds to generate thoughts--and even precepts [sic]--of other persons round about him" (p. 180).

The use of analogy is especially commonplace in the classroom. Teachers often use analogies as a method of simplifying difficult concepts for students by associating them with familiar events or objects. The analogy between the motion of billiard balls and the behavior of gas particles is one such example.

Analogous relationships are basic to all fields of study (Black & Black, 1986). In an address to the American Psychological Association, Oppenheimer (1956) extolled the analogy as "an indispensable and inevitable tool for scientific progress" (p. 129). When faced with new phenomena, scientists explain them by falling back upon analogies with the old and familiar.

Purpose of the Study

Due to the pervasiveness of analogies in the educational system as well as everyday activities, the development of analogical reasoning in children deserves further investigation. For the most part, previous studies on analogical reasoning skills in children have concentrated on the use of word analogies. It is hoped that this study will provide information on children's performance on tasks involving several modalities.

Few studies have assessed the relative difficulty of the different modalities for children. Feuerstein (1979) suggested that verbal analogies, because of their complex semantic relationships, are more difficult to solve than figural ones. Verbal items are also more dependent upon cultural background and experience. There is evidence that children can semantically process pictorial stimuli more quickly than verbal stimuli is quicker in children (i.e., second and fifth graders); however, the latency difference declines with age although it remains significant in young adults (i.e., college undergraduates) (Hogaboam & Pellegrino, 1978; Pellegrino, Rosinski, Chiesi, & Siegel, 1977; Rosinski, Pellegrino, & Siegel, 1977). It is not known how the ability to process pictorial stimuli quicker than verbal stimuli affects the ease or difficulty of solving word versus picture analogies is not known.

The performance of males versus females on analogical reasoning tasks has not been addressed by many researchers. A study by Mulholland, Pellegrino, and Glaser (1980) did find that females consistently solved geometric (figure) analogies faster than males although they also made more errors (e.g., 9% versus 7%).

This study was designed to study the performance of normal children in the fifth, eighth, and eleventh grades on a multi-modality analogy task involving stimuli presented in word, picture, and geometric forms. It was hypothesized that the results of the study would confirm the findings of previous studies that analogical processing skills do increase with age.

The following experimental questions are of interest:

- 1) Do fifth, eighth, and eleventh graders perform differently from each other on analogical reasoning tasks?
- 2) Is one type of analogy more difficult to solve than another (e.g., Are picture analogies more difficult than figure analogies or vice versa)?
- 3) Do males and females perform differently from each other on analogical reasoning tasks?

CHAPTER II

REVIEW OF THE LITERATURE

Types of Analogies

Formal analogy test items are found in the form of "A is to B as C is to D" ($A:B::C:D$), where the last term (D) is usually omitted and must be filled in, either through spontaneous generation or through selection of alternative answers (Sternberg, 1982). The presentation of the terms in the form A is to B as C is to ? is referred to as the stem of the problem. The most typical form of analogy presentation is one composed of words; however, the format may involve figures or geometric forms. Guilford (1967) described a Cartoon Analogies test which consisted of analogies involving facial expressions and body parts.

Verbal Analogies

Ten of the most common types of verbal analogies appearing on analogy tests are (1) word: synonym, (2) word: antonym, (3) cause: effect, (4) part: whole, (5) condition: lesser degree of the same condition, (6) condition: greater degree of the same condition, (7) person or thing: characteristic or quality (e.g., athlete: healthy), (8) person or thing: group or category (e.g., painter:

artist), (9) person or thing: action or function, and (10) worker: device he/she uses (Liebman, 1988a). Word analogies appear in many tests, including the Scholastic Aptitude Test (SAT), The Lorge-Thorndike Intelligence Tests, the Stanford-Binet Tests of Intelligence, the Graduate Record Examination (GRE), and the Miller Analogies Test. They are the most widely recognized type of analogy.

Pictorial Analogies

Pictorial analogies are identical to verbal analogies except for the fact that pictures are presented rather than words. They are especially useful for testing children who are too young to read or who have reading deficits (Nippold, Erskine, & Freed, 1988; Lorge & Thorndike, 1957). Typical analogical relationships expressed in pictorial analogies are identical to those cited above for word analogies.

Geometric Analogies

Typical items in a geometric analogy include two-dimensional figures such as lines, circles, triangles, and quadrilaterals (Mulholland et al., 1980). These figures may be transformed or altered in different manners to produce analogical relationships between terms. For instance, transformations may include removing, adding,

rotating, mirroring or displacing elements. Other possible alterations are a change in size or variation in shading of the figure. Geometric analogies are unique in that linguistic processing is not necessary for solving them. Instead knowledge of spatial relations and the ability to visualize are required. The development of mental rotation, defined by Sternberg (1985) as involving the ability to "rapidly and accurately engage in mental rotation of one or more visualized objects" (p. 104), was studied in childhood, adolescence, and adulthood by Kail, Pellegrino, & Carter (1980). Children as young as eight were able to perform mental rotation on task items, and as hypothesized the rate of mental rotation was significantly faster in adults than in third and fourth graders. In an attempt to explain this developmental change, the authors proposed that adults rotate only the significant part of the stimulus whereas children rotate the entire stimulus. However, their data were insufficient to support this hypothesis. Increasing the number of transformations involved in an analogy has also been found to increase solution time (Mulholland et al., 1980).

Analogies and Inductive Reasoning

Complex cognitive abilities are classified into two types: inductive and deductive reasoning. To reason inductively requires an individual to reason from part to

whole or from particular to general (Sternberg, 1985). Inductive reasoning problems are characterized by the absence of a single, logically certain response. One solution may appear to be better than the alternatives, however, this solution is consensually agreed on rather than being logically necessary. Inductive reasoning tasks include analogies, metaphors, and series completion. In deductive reasoning tasks, the information needed to logically reach a valid conclusion is contained in the premises of the problem. Linear, categorical, and conditional syllogisms test for deductive reasoning abilities (e.g., "Sarah is taller than Jane. Jane is taller than Judy. Who is the tallest?"). Inductive reasoning performance is considered a keystone of intelligence (Sternberg, 1985). In the following section, a prominent theory of inductive reasoning and its relationship to analogical reasoning will be considered.

Sternberg (1977b; 1985; Sternberg & Rifkin, 1979) proposed The Componential Theory of Analogical Reasoning in an attempt to explain how inductive reasoning is used to solve analogy problems. It is composed of six information processing components: (1) encoding, by which the relevant attributes of the terms are stored in working memory, (2) inference, by which a relation between the A and B terms is determined, (3) mapping, by which the first half of the analogy is linked to the second half by find-

ing a relation between the A and C terms, (4) application, by which each answer option is evaluated in terms of providing a relation to the C term which is analogous to the relation expressed by the A and B terms, (5) justification, by which the answer option which most closely corresponds to the relation between the A and B terms is chosen if an exact match cannot be found, and (6) response, by which the correct answer is communicated. Among these six processes, Sternberg considers all but justification as mandatory in solving analogies. Research has provided support for the componential theory (Sternberg, 1977a, 1977b), although, Whitely and Barnes (1979) proposed that Sternberg's fifth component process of application should be described as two separate events, image construction and response evaluation.

In addition to this general model, Sternberg and Rifkin (1979) developed four procedural models (I, II, III, IV) which differ in whether or not the component processes are exhaustive or self-terminating. For instance, in Model II, inference and mapping are exhaustive, but application is self-terminating. The subject must infer and map all possible relations between the terms. Since application is self-terminating, the subject only needs to apply as many attribute values as necessary to choose an appropriate answer. The authors hypothesized that the use of a self-terminating process would be more efficient and

therefore, more mature subjects would be prone to use one. However, they found that younger children are more likely to use self-terminating models than older children and adults. They hypothesized that this trend might be attributed to the inability of younger children to store all of the information provided by an exhaustive process. Use of self-terminating operations was also linked to greater error rates in younger children.

Development of Analogical Reasoning

Studies vary in their estimation of the age at which analogical reasoning begins. However, it is generally agreed that 11 and 12 year old children are capable of such complex processing when it involves analogies in the form A is to B as C is to D (Gallagher & Wright, 1979; Levinson & Carpenter, 1974; Sternberg & Nigro, 1980). Several studies have investigated the presence of analogical reasoning skills in younger children and found them to be present to a limited degree even in preschoolers when using a less structured form (Gentner, 1977; Goldman, Pellegrino, Parseghian, & Sallis, 1982; Holyoak et al., 1984; Levinson & Carpenter, 1974). A problem often noted in younger children (less than twelve years of age) is their susceptibility to experimenter-provided countersuggestions and a tendency to respond by choosing terms which have a high degree of association with the stem word

(Achenbach, 1969; Gallagher et al., 1979; Goldman et al., 1982; Sternberg & Nigro, 1980). For example, in the analogy "Five is to number as black is to ?," it has been shown that younger children will respond with the answer "white" because it has a high frequency association with "black" rather than with the correct answer "color." Analogical reasoning has been shown to improve throughout a child's school years (Levinson & Carpenter, 1974).

Verbal analogies were one of the items tested in the Iowa State Study, a long-term longitudinal study of intelligence which spanned forty-two years (Schaie, 1983). Subjects consisted of 363 freshmen from Iowa State College who were tested in 1919 with the Army Alpha Test. In 1950 and 1961, all available subjects (127 and 96, respectively) were retested. Results indicated a slight gain in analogy subtest scores. The researchers speculated that this unexpected increase was due to cultural differences (i.e., analogy tests were unfamiliar in 1919 but had become more widely known within the culture over the several decades of the two retests). This study indicates that adults seem to maintain their analogical reasoning skills at least until age 60 without any overall decline; although, the loss of such a great number of subjects between retestings warrants cautious interpretation.

Analogical Reasoning in Older Children

Goldman et al. (1982) examined the sources of skill differences in verbal analogical reasoning in third and fourth grade children. The first of two experiments involved presenting the children with 50 analogies in a generation task, and later, the same analogies in a forced choice task. In the generation task, the children were presented with examples and coached on how to solve the analogy i.e. "...you figure out how the first two words go together, then you should think about a word that goes together with the third word in the same way" (p. 552). The examiner orally read each stem of three words and presented them on a card. Two weeks later, the forced choice task was presented to each child with the instructions to "think about how A and B go together and then pick a word that makes C and the response go together in the same way" (p. 553). The child was also asked to justify the response orally. A second experiment involved three tasks: relational inference, generation, and forced choice. For the relational inference task, the child was asked to tell how the first two terms of the analogy went together (e.g., In the example, "dog is to bark as cat is to ?" how are "dog" and "bark" related?). The generation and forced choice task were the same as in the first experiment.

The results of these two experiments indicated that even when justifying a correct response, less skilled analogical reasoners were likely to refer to an irrelevant or nonexistent relation rather than the parallel relation between the two sets of terms. Younger or less skilled reasoners were also more susceptible to alternative terms that have a high degree of association with the C term. The authors proposed that this might be due to weak analogical processing giving way to a simpler associative solution strategy in face of demands beyond the child's capability. Of special interest was the fact that skilled third graders were able to perform better than less skilled fifth graders.

Levinson and Carpenter (1974) investigated analogical reasoning skills in 9-, 12-, and 15- year-old children using two forms of verbal analogies: quasi analogies and true analogies. Quasi analogies restructured the typical analogy form (i.e., bird is to air as fish is to ...) by putting it into sentence form (e.g., a bird uses air; a fish uses...). Their primary interest was in determining whether age made a difference in solving the two types of analogies and whether an understanding of proportional relationships aids true analogical reasoning. Subjects were divided into two subgroups: one which was given the quasi analogies first and one which was given the true analogies first. A week later each group received the

opposite test. In addition, two subjects from each subgroup were chosen randomly to provide explanations for their responses. The 9-year old children demonstrated an emerging ability to reason analogically, although they were less able than the 12- and 15- year olds. Further, some of the 9-year olds were able to provide adequate justifications for their responses to the analogies, which suggests an understanding of proportional relationships. The scores for 9-year old subjects were significantly higher on the quasi analogies than on the true analogies. This was not found to be true for the older children, whose performance did not differ significantly for the two types.

To explain the difference for the 9-year olds, Levinson and Carpenter (1974) suggested that although all of the stimulus words were considered to be appropriate for their chronological age, perhaps the children had not yet acquired the semantic features necessary to map all of the possible relations between the analogy terms. This lack would limit their ability to consider all of the possible relationships between the word pairs. The inclusion of semantic features in the quasi analogy forms supplied additional information to the subjects. The improved performance of 9-year olds on quasi analogies suggests that they may be used as an avenue to teach analogical

reasoning to children deficient in this skill as well as to teach semantic features.

The roles of concrete versus formal reasoning in solving verbal analogies were investigated by Lunzer (1965). He increased the difficulty of solving verbal analogies by decreasing the familiarity of their terms, and introducing a greater complexity of form (e.g., "rest/shelter/food/thirst is to water/hunger/house/bed as clothes is to warmth (p. 33)"). It was theorized that the additional difficulty would require the use of formal reasoning as opposed to concrete reasoning.

Lunzer (1965) assumed that simple analogies of the form, "Bird is to fly as fish is to swim" only require concrete reasoning. Results indicated that children do not experience success with even the simplest of verbal analogies until they are 11 to 12 years old, which is the beginning of the formal reasoning stage according to Piaget. Sternberg and Nigro (1980) found that analogical reasoning in children still in the concrete operations stage tends to be incomplete rather than absent.

Analogical Reasoning in Preschoolers

Although it is generally accepted that the ability to process analogies in the traditional form of A is to B as C is to D is not successful until the child is at least 12 years old, some researchers have attempted to alter the

traditional analogy task in an effort to simplify the task for younger children who do not yet possess verbal skills adequate to accomplish the standard analogy task.

Gentner (1977) devised two spatial analogies tasks for preschoolers using body-parts, called the Orientation and Local Features tasks. A typical Orientation task involved asking the child "If this [pictured] mountain had a knee, where would it be?" (p. 1034). In general, the task involved mapping body parts onto pictured trees and mountains, which were placed in various positions such as upside down or lying on their sides. The Local Features Task required subjects to map eyes and mouths onto mountains which already had eyelike and mouthlike details drawn on them to resemble a human face. The details were placed in a typical eyes over mouth pattern as well as in atypical facial patterns (e.g., the mouth over the eyes). The subjects consisted of 10 preschoolers, 10 first graders, and 10 college sophomores. The subjects' performance was judged by adequacy of the placement of the body part on the object, i.e. whether the placement was proportional in respect to the object's height. There was no significant age effect on the Orientation task for any of the groups. However, on the Local Features task, both the preschoolers and first graders did significantly better than the adults. The author attributes this finding to the fact that the adults were more apt to use the

pre-drawn details as references than the children even though the details were not in the correct positions. Gentner concluded that basic analogical reasoning skills are present and well developed in preschool children.

Analogical Reasoning in Transfer Tasks

Analogical thinking may be considered the transfer of knowledge from one situation to another by the process of mapping (Holyoak et. al, 1984). Many experiments focus on how individuals solve standard analogy problems, thus providing useful information; but this is an artificial condition only experienced in formal testing situations. People use analogical thinking every day to solve novel problems by comparing the current situation to an already known situation. Several studies will be discussed which attempted to determine if subjects transfer known solutions to a problem to a novel yet analogous problem.

Holyoak et al. (1984) asked preschoolers and fifth and sixth graders to solve a problem which allowed multiple solutions. Some of the children were first read one of two stories which included a problem and its solution which were analogous to the problem they were required to solve. A control group was not read either of the stories. The stories involved a genie who wanted to move his home from one bottle to another and needed to discover a way in which to move his precious jewels to the new

bottle safely. In the story called the "Magic Staff," the genie used his magic staff to pull the new bottle next to his old bottle. The solution to the "Magic Carpet" story had the genie roll his magic carpet into a tube and use it as a bridge between the two bottles to roll his jewels through. After the children listened to the appropriate story, two bowls were set on a table, one within the child's reach and the other farther away. The closest bowl contained gumballs and the other was empty. The following materials were also placed on the table: an aluminum walking cane, a large sheet of heavy paper, a hollow cardboard tube, child-safe scissors, string, tape, paper clips, and rubber bands. The subjects were asked to devise as many solutions as possible for moving the gumballs to the empty bowl. For the magic carpet condition, subjects were expected to roll the paper into a tube and roll the gumballs through it just as the genie rolled his jewels through his carpet. Using the walking cane to pull the empty bowl closer was felt to be analogous to the genie using his magic staff to move the bottle. If the children were not able to propose the analogous solution, the examiner asked "Does anything in the story help?" and "What did the genie do and could you do anything like that (p. 2045)?"

Results indicated that all of the preschoolers in the magic staff condition were able to suggest the cane solu-

tion to the problem whereas only one subject in the other two conditions was successful. However, only three of the preschoolers produced the analogous solution when presented with the magic carpet story. This may be due to the fact that the children had to go through more steps to create a tube than the genie did; i.e., the genie did it magically whereas the children had to roll the paper and then decide how to keep it rolled. All of the fifth and sixth graders in the magic carpet condition were able to derive the analogous solution whereas none of the control subjects offered it. These results indicate that even preschoolers possess the ability to use analogies to solve real problems.

The transfer abilities of 2-4 year old children were examined in an experiment by Crisafi and Brown (1986). The experiment involved three different tasks in which the objects used and the relations among them were either familiar or unfamiliar to the children. For the first task, the child "learned to find a penny or a dime in a purse or a piggy bank and then learned that inserting the correct coin into a gum-ball machine produced a gum ball" (p. 957). This task utilized objects familiar to the child and the relations among the objects was also familiar. The two other tasks demanded the same solution. In the second, the child needed to find a coin with which to release a piece of candy from a dumptruck. The dumptruck

was a familiar object; however, the relations among the truck, candy, and coin were novel. The third task required the child to use a nut cap or small piece of copper tubing as if it were a coin to release a gum ball from a plastic box with three drawers. The objects and relations in this task were arbitrary and unfamiliar.

The authors discovered that even 2-year olds are able to demonstrate transfer on analogy tasks under certain circumstances. Placing children in familiar settings with familiar objects was found to be a factor in facilitating task completion. Children can be assisted in promoting transfer by (a) emphasizing the similarity of the tasks and (b) encouraging them to discuss the rules which leads to recognition of problem similarity. The most frequent source of failure on transfer tasks is the inability to notice similarity between problems. This is true not only of young children but adults as well, as Gick and Holyoak (1980) and Reed, Ernst and Banerji (1974) discovered when testing the transfer abilities of undergraduate college students. Transfer frequency was also reduced when the proposed problems were disanalogous in any way (Crisafi and Brown, 1986; Gick and Holyoak, 1980).

Analogical Reasoning and Multiple Intelligences

Intelligence may be expressed in a variety of different ways. A young boy or girl may excel at geometry,

another may be a great poet, and yet another may be a star athlete. The first two instances are invariably thought of as expressing intelligence whereas the third may be seen as merely a physical ability which has no basis in intellectual functioning. In his book Frames of Mind, Gardner (1985) proposed that there are not one or two types of intelligence, but seven. This theory of "multiple intelligences" presumes that the intelligences are separate and independently measurable rather than unified in a "g factor." Gardner considers the seven intelligences to be: linguistic, musical, logical-mathematical, spatial, bodily-kinesthetic, interpersonal, and intra-personal. The star athlete possesses bodily-kinesthetic intelligence. Gardner's theory has interesting implications for the individual variance seen in performance on multi-modality analogies. An individual with a high degree of spatial intelligence may be expected to perform better on figural than verbal analogies. If a high degree of linguistic intelligence is present, verbal analogies may be easier than figural analogies.

Guilford's "Structure of Intellect" model is another well-known theory which suggests that there are many factors involved in intelligence. Guilford (1967) proposed three main categories which compose the structure of intellect: content, operations, and product. He further subdivided the category of content into (a) figural, (b)

symbolic, (c) semantic, and (d) behavioral, all of which represented modalities. The operations category was broken down into: (a) evaluation, (b) memory, (c) cognition, (d) convergent production, and (e) divergent production. Lastly, the product category included six types: (a) units, (b) classes, (c) relations, (d) systems, (e) transformations, and (f) implications. Through all of these categories and subcategories, Guilford attempted to isolate and test for the various factors of intelligence.

Tests of Analogical Reasoning

Several types of analogical reasoning tasks have been used in test instruments. Given that analogy tasks are considered to be a good indication of the "g" factor of intelligence (Spearman, 1927), they are a popular item on intelligence tests. Guilford (1967) used verbal and figural analogies to measure different aspects of intelligence. He found that the best type of measure for Cognition of Figural Relations (CFR) was a figure-analogies form. One such test was the Figure Matrix test which placed geometric figures in three by three matrices rather than the traditional two by two arrangement. One or more cells would be blank and the subject was required to deduce what kind of figure should appear there. Guilford found verbal analogies were found to be the best measure of Cognition of Semantic Relations (CMR). Similar to the

Figure Matrix test, he constructed a Word Matrix test with two rows and three columns of words (e.g., ground: street: automobile:: air: route: ?).

Several other analogy subtests are currently available. The Test of Nonverbal Intelligence (TONI) (Brown, Sherbenou, & Johnsen, 1982) assesses nonverbal problem solving in subjects ranging from 5-0 to 85-11 years. Figural analogies are one of the five types of nonverbal problems tested. Reliability studies with deviant populations (i.e., educable mentally retarded, hearing impaired, and learning disabled) showed that the TONI is internally consistent and stable when used with these populations.

The Lorge-Thorndike Intelligence Tests (Lorge & Thorndike, 1957) include pictorial analogies as one of three Nonverbal Battery Subtests and verbal analogies as one of the five Verbal Battery Subtests. The pictorial analogies are intended to allow students deficient in verbal processing skills to show their true potential using a non-linguistic modality. The Nonverbal and Verbal Battery tests may be given to students in grades 3 - 13 and a Primary Battery using only pictorial items is included for students from kindergarten up to the third grade. The norms provided for this test are based on a sample of over 136,000 children in 44 different communities and 22 states.

The Ross Test of Higher Cognitive Processes (Ross & Ross, 1976) assesses the ability to solve verbal analogies in one of its eight subtests. Students are given an analogy to solve in the traditional format "A is to B as C is to ?" with the possibility of five answers. Due to the minimal number of analogies tested (14), results should be interpreted with caution.

The Learning Potential Assessment Device (LPAD) is a unique instrument designed by Feuerstein (1979) to assess the cognitive functioning of educationally and culturally retarded individuals. Culturally retarded individuals were defined by Feuerstein as individuals who have become alienated from their own culture which "is reflected in a disruption of intergenerational transmission and mediational processes" (p.39). He believed that conventional tests could not provide insight into the true potential and abilities of these individuals. He selected verbal analogies for testing because he believed them to be the major area of deficiency in his target populations. Figural analogies were of interest because of the many factors involved in their design (e.g., spatial orientation, evaluation of size and closure). Results from individual performances on the LPAD were used by Feuerstein to develop remedial and instructional strategies for training the cognitive functions necessary for solving analogies.

Therapy Materials for Teaching Analogical Reasoning Skills

Analogies are used frequently in educational settings to elucidate and clarify difficult concepts for school children. However, when a child has a language impairment or learning disability, the complex processing necessary for solving analogies may be beyond his or her capabilities. Nippold et al. (1988) found that language impaired children had more difficulty solving verbal and figural analogies than did normal subjects. Analogical reasoning could be used as a technique for identifying children with mild or moderate linguistic deficits (Nippold, 1986). In such cases, the teacher's attempt to help the student learn through analogy may backfire and inadvertently confuse the child. Such students need to be taught the steps involved in analogical processing. Similarly, retarded or brain-injured individuals may lack the ability to reason analogically. Efficiency in the use of analogical reasoning by mentally retarded individuals can be improved through appropriate training strategies (Feuerstein, 1979). In a study by Gillespie (1987), brain damaged individuals, both right and left hemisphere, showed more difficulty with analogical reasoning than did normal individuals.

Several workbooks and computer software programs are available to aid therapists in teaching analogical pro-

cessing skills to impaired clients. Liebman (1988a, 1988b) wrote the workbooks Analogies 2 and Analogies 3 to aid students in preparing for standardized tests such as the Scholastic Aptitude Test (SAT). These books may also be used by individuals impaired in analogical processing, although they are fairly high level. Liebman offers techniques for solving analogies and provides explanations for each analogy's solution. The reader is taught to use sentences to bridge together analogy terms; e.g., blood: vein may be bridged together as "Blood goes through a vein" or "A vein carries blood". The correct answer should fit right into the bridge sentence. Levinson and Carpenter (1974) used the term "quasi analogies" to describe analogies utilizing bridge sentences. They suggested that quasi analogies may be used as a technique for teaching analogical reasoning skills to children deficient in that skill. In addition, they could be used to teach semantic features of words. The importance of defining all of the possible semantic features of a word is also stressed in Liebman's workbooks by focusing on words which have multiple meanings.

A four book series by Black and Black (1986, 1987a, 1987b, 1988) titled Building Thinking Skills focuses on skills which lead to the development and improvement of analogical reasoning. For instance, a student may work on matching figures, dividing shapes into parts, enlarging

and reducing figures, recognizing directions, and rotating figures. These tasks all build upon the base of knowledge a student needs to solve figural or geometric analogies. Verbal and figural analogies are included in all of the books. The series provides a teacher's manual as well as workbooks for the students.

The Workbook of Activities for Language and Cognition (WALC) (Tomlin, 1986) is available in book form or as a computer program for the Apple lle or llc. It contains a number of exercises designed to aid in the remediation of language and cognitive skills in adolescents and adults. Open-ended verbal analogies such as "Hot is to cold as left is to ?" are among the many tasks available. The clinician must provide feedback and interact with the client to teach the necessary steps for processing the analogy accurately. It would be difficult for even moderately impaired individuals to use this program without assistance.

Remedia Educational Software publishes the program Analogies (1987), which provides teaching hints as well as positive reinforcement for the client. Only verbal analogies are provided in this program. A pre-test allows the clinician to determine at which of three levels of difficulty the client should begin. A nice feature of this program is the record-keeping system for keeping track of a client's progress.

CHAPTER III

METHODOLOGY

Subjects

This study included 201 students from the 5th, 8th, and 11th grades in the school district of Mattawan in Van Buren County. Mattawan is a predominantly white, middle class, rural community. Each of the three grades supplied three classrooms which ranged in size from 14 to 30 students. 68 fifth graders (41 males and 27 females), 66 eighth graders (31 males and 35 females), and 77 eleventh graders (34 males and 43 females) were tested. All fifth graders were tested in their language arts classrooms which were taught by three different teachers. Students from two Algebra classes and one history class were tested in the eighth grade. All eleventh grade subjects were taken from three English classes all of which were taught by the same teacher. One of the classes was an honors section.

Pertinent information on the students was gathered at the time of testing. Students were asked to provide their date of birth and sex on their answer sheets. The ranges, means, and standard deviations for the subjects' ages are summarized in Table 1.

TABLE 1
Age Range, Means, and Standard Deviations
for the Experimental Groups

Group	N	Range	Mean	SD
Fifth	68	9:11 to 11:10 years	10:9	5.8 months
Eighth	66	12:1 to 14:10 years	13:6	6.7 months
Eleventh	77	15:11 to 17:9 years	16:8	6.0 months

Any students who failed to provide this information were excluded from the analysis ($n = 5$). Student names were not recorded at any time, to ensure confidentiality. Confidentially, teachers were asked if any of the students (1) were currently in or had been referred to Special Education, (2) had a known hearing loss, (3) spoke a language other than English as their native language, and/or (4) were being treated for a language disorder by a speech-language pathologist. The performance data of such students was analyzed along with the other students. It was felt that if the students were able to function in a regular mainstreamed classroom then they should be included in the testing. Only one student from the eighth grade met any of the above mentioned criteria. He was currently enrolled in Special Education. This student's results will be discussed indi-

vidually at a later time. Age requirements were lenient; only students differing from the age mean for their grade by more than two years were omitted from the analysis. This situation only occurred once. A fifth grade girl indicated that she was 14 years and 1 month old, which was three years over the mean for the fifth graders.

Subject Consent

In order to obtain the approval of the Mattawan school district for testing, initial contact was made by phone to receive tentative approval for testing. Letters were sent to the superintendent and principals (junior high and high school) explaining the study and providing details on how and when the testing would take place. Initially, contact was made by phone to receive tentative approval for testing. Upon gaining final school permission, informational letters were sent home to parents explaining the study and what would be required of their children (See Appendix A for a copy of the information letter). Parents were informed of their right to refuse their child's participation in this study and to withdraw at any time without penalty. In addition, the letter stated that students themselves would be given the chance to refuse participation at any time before or during testing. Parents were further informed that their child's name would not be used at any time, to ensure confidentiality. Parents who

wished to exclude their child from this study were asked to contact his/her teacher before the day of testing. These methods were approved by the Western Michigan University Human Subjects Institutional Review Board (See Appendix B).

Stimuli

Sets of analogies, constructed in three modalities: words, pictures, and geometric figures, were provided by Nickola Nelson of Western Michigan University and Letitia Gillespie of Case Western Reserve University, who are currently working with Communication Skill Builders Publishing Company to publish intervention materials for solving analogies in three modalities. Their project stems from a master's thesis by Gillespie (1987) on the effects of unilateral brain damage on analogical reasoning skills. The analogy items used in that study have been expanded upon for the current study.

Thirty analogies in each set were provided for a total of 90 analogies. The 90 analogies were assigned to three levels of difficulty denoted as Level A (easy), Level B (medium), and Level C (hard). These classifications were based on (1) the vocabulary used and (2) the complexity of the analogical relationships. To assess the difficulty of the words used for the word analogies, Nelson and Gillespie (in press) used data compiled by Stemach and

Williams (1988) for their book Word Express. Stenach and Williams gathered the first 2500 words of spoken English used in spontaneous spoken language samples from over 500 first graders and divided them into 10 levels of 250 words each. The words in Level 1 and 2 accounted for approximately 85 percent of all of the words spoken by first grade children according to the authors. In selecting vocabulary for the word and picture analogies, Nelson and Gillespie used the following three guidelines: (1) Level A vocabulary was drawn from Levels 1, 2, and 3, (2) Level B vocabulary was drawn from Levels 4, 5, and 6, and (3) Level C vocabulary was drawn from Levels 7, 8, 9, and 10.

Furthermore, word and picture analogies were represented by the following eight relationships (Nelson & Gillespie, in press):

- (1) antonyms (up:down::top:bottom);
- (2) synonyms (easy:simple::hard:difficult);
- (3) functional (knife:cut::pencil:write);
- (4) part-whole (page:book::teeth:mouth);
- (5) member-class (red:color::square:shape);
- (6) cause-effect (match:fire::refrigerator:chill);
- (7) degree (good:better::bad:worse);
- (8) characteristic property (wheel:round::arrow:straight) (p. 33).

Figural analogies were based on the set of structural relationships used in constructing the analogies for The Test of Nonverbal Intelligence (TONI; Brown et al., 1982). Nelson and Gillespie defined the relationships as (a) matching (no difference between figures A and B is matched in the identical relationship between figures C and D); (b) addition (figures A and C are changed into figures B and D, respectively, by adding attributes or parts); (c) subtraction (figures A and C are changed into figures B and D, respectively, by subtracting attributes or parts); (d) alteration or rotation (figures or attributes are moved in some systematic way to change figures A and C into B and D); and (e) progression (a continuum of change appears among or between figures") (p.34).

All of the analogies were presented using a four-frame box-type arrangement (see examples of each modality analogy in Appendix C). A completed relationship appeared in the upper two boxes (A:B) while a parallel stimulus (C) appeared in the bottom left box. The bottom right box was empty. Thus, the analogical reasoning format of "A is to B, as C is to D" was provided by this arrangement. Subjects were given three possible answer choices which appeared in boxes at the bottom of the page. The answers were numbered with the numerals "1," "2," and "3," printed below each response choice.

Procedures

Subjects were tested in group sessions in their regular classrooms. 8 1/2 X 11 in. transparencies were made of the analogies for use on an overhead projector. The analogies were presented on the projector one at a time. Each subject solved 30 analogies in each modality, with 10 at each level of difficulty, for a total of 90. The analogies were presented in order of difficulty (i.e. first, Level A, then Level B, and Level C last). The modalities were presented in the order of words, pictures, and figures within each level (i.e, Level A: words, pictures, figures; Level B: words, pictures, figures; Level C: words, pictures, figures). Before presenting the Level A analogies, a practice item was given for each type of modality to familiarize the subjects with the task. The transparencies with the practice items were placed on the overhead projector preceding each presentation of a new modality. The examiner asked the entire class what the answer was by pointing out each box of the frame and the response choices by saying "This is to this as this is to this, this, or this?" The subjects responded by answering in chorus.

Level A items were left on the overhead projector for ten seconds. At the end of eight seconds, the examiner would remark "Pick your answer please" which left the

subjects an additional two seconds to scan the response choices and fill in the answer sheet. Subjects were allowed a longer period of twenty seconds for the Level B questions, and an even longer period of thirty seconds for Level C items to adjust for the increased difficulty of the analogies. These time limits were chosen on the basis of a pilot study conducted by the examiner with a group of college students at Western Michigan University. These students had received the same analogy problems in the same order but were given only ten, fifteen, and twenty seconds for Level A, Level B, and Level C items, respectively. After testing, the college students were informally surveyed by the examiner in an effort to detect any problems with the test presentation or time limits before proceeding with testing the younger subjects. It was agreed almost unanimously that not enough time had been allotted for Level B and C items. Therefore, the time limits were adjusted to the limits discussed above.

The time required to complete all three tasks was approximately 35 minutes; an additional 10 minutes was needed for instruction and preparation period. At the start of each session, each subject was given a computer answer sheet and a number 2 pencil to use with it. These were distributed at the beginning of the test session with the instructions not to put any names on the score sheets. A transparency of the answer sheet was placed on

the overhead projector to show what information was needed from the subjects and how their answers were to be marked. Subjects were asked to fill in date of birth and sex in the areas indicated by the examiner. They were notified that each answer circle must be filled in completely and no marks were to be made outside of the circles. The answer sheet contained blanks for five possible responses but the students were alerted to the fact that there would be only three possible response choices on the test items so the remaining two blanks should be ignored. A complete dialogue used by the examiner can be found in Appendix D.

CHAPTER IV

RESULTS

In this study, analogical reasoning was measured by having subjects complete 30 analogy problems each in the three modalities, words, pictures, and figures. Each correct response was awarded a value of one point, yielding a maximum score of 30 points per modality and 90 points overall. The summary of the mean raw scores for each grade is shown in Table 2. In addition, a graph of the mean scores for the three modalities at each grade level may be found in Figure 1.

The data were analyzed using the following procedures: (a) repeated measures analysis of variance (ANOVA) for the three main effects (grade, class nested within grade, and sex), (b) post hoc analysis comparing performance differences between grades on the task, and (c) post hoc analysis comparing performance differences on the three modalities (word, picture, and figures). Finally, in order to explore the interaction between grade and modality, simple effects of each independent variable at each level of the other independent variable were tabulated.

Repeated Measures Analysis of Variance

A repeated measures analysis of variance (ANOVA) for the three analogical reasoning tasks is summarized in

Table 3. The ANOVA calculated the following effects: (1) main effect for grade, sex, and class nested within grade, (2) main effect for repeated measures (i.e., analogy tasks), and (3) interaction effects for repeated measures and the independent variables.

Table 2
Group Mean Scores for the Three Analogical Reasoning Tasks

Group	Group Means
Fifth Graders	W = 20.16
(N = 69)	P = 22.47
	F = 23.22
Eighth Graders	W = 22.46
(N = 67)	P = 24.14
	F = 25.24
Eleventh Graders	W = 24.13
(N = 77)	P = 25.69
	F = 25.45

Note. W = Word Set; F = Figure Set; P = Picture Set.

These statistical measures were conducted using a program known as the Clear Lake Research ANOVA (CLR ANOVA) (1986), an analysis of variance program for the Apple Macintosh, with additional computations to allow for nesting

of the class variable within grade. To control for the unequal subject groups in this study, CLR ANOVA used unweighted marginal means in the ANOVA analysis.

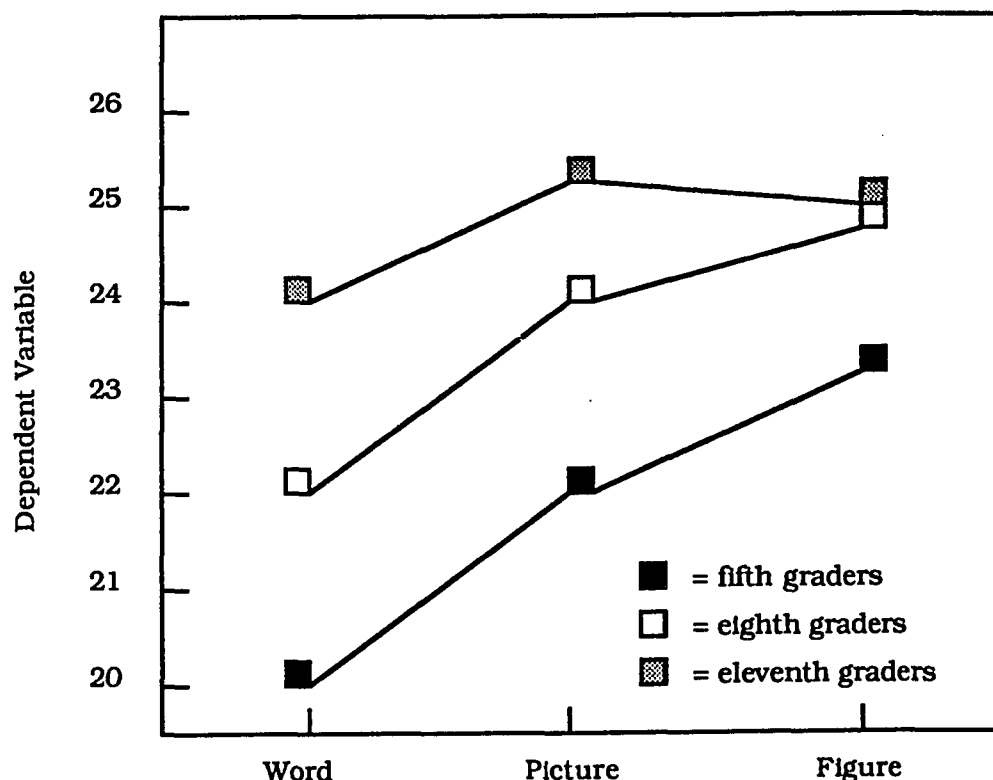


Figure 1. Mean Scores for the Grades on the Three Analogy Tasks.

The main effect for grade was found to be significant ($F = 48.24$; $df = 2, 193$; $p < .001$), indicating significant differences among the three groups of subjects. The main effect for modality was also significant ($F = 72.17$; $df = 2, 386$; $p < .001$), indicating a significant difference among the three analogy tasks. Sex was not found to be a

significant factor ($F = .199$; $df = 1, 193$; $p > .05$), indicating that there was no differential performance between sexes. The main effect for class nested within grade also was not found to be significant ($F = .4678$; $df = 6, 193$; $p > .05$) indicating that the class in which a subject was tested did not significantly affect performance. Finally, the grade-by-modality interaction effect was found to be significant ($F = 3.89$; $df = 4, 386$; $p < .01$), indicating that the three groups experienced the three modality tasks differentially. Due to the significant findings for the grade effect, the modality effect, and the interaction effect between grade and modality, post hoc comparisons were deemed appropriate in order to determine specific areas of significant difference. The Newman-Keuls procedure was used for all post hoc analyses.

Differences Among the Fifth, Eighth, and Eleventh Graders on the Three Analogy Tasks

The analysis of variance showed that the main effect for grade was significant, which indicates that the performances of children in the three grades were not all alike. Post hoc analysis using the Newman-Keuls procedure further showed that each grade was significantly different from each of the other grades at the .01 level (see Table 4). Given that the mean scores for the eleventh graders were higher than those of the fifth and eighth graders,

and the scores for the eighth grade were higher than those for the fifth grade, it can be concluded that the ability to solve analogies increased with each succeeding grade level. This confirms the initial hypothesis that analogical reasoning skills, as measured by items of the types used in this experiment, do increase with age.

Table 3
Repeated Measures Analysis of Variance

EFFECT	SS	<u>DF</u>	MS	F	<u>P</u>
A	944.68	2	472.34	48.24	.000
B(A)	541.76	6	90.29	.47	>.05
C	.20	1	.20	.02	.887
AC	24.76	2	12.38	1.26	.285
BC(A)	66.75	6	11.12	.06	>.05
Error 1	1889.8	193	9.79		
D	588.13	2	294.06	72.17	.000
AD	63.47	4	15.87	3.89	.004
BD(A)	41.35	12	3.45	.01	>.05
CD	3.93	2	1.97	.48	.618
ACD	19.04	4	4.76	1.17	.324
BCD(A)	66.74	12	5.56	.01	>.05
Error 2	1572.8	386	4.08		

Note. A = Grade; B = Class; C = Sex; D = Modality.

Table 4
Newman-Keuls Pairwise Comparison of Grades

	Fifth	Eighth	Eleventh
Fifth	X		
Eighth	<.01	X	
Eleventh	<.01	<.01	X

Fifth Graders' Performance

The fifth graders' mean scores for the three analogy sets were: (1) 20.16 for the Word Set, (2) 22.47 for the Picture Set, and (3) 23.22 for the Figure Set. Performance on the Word Set was the lowest while a slightly better performance was seen for the Picture and Figure Sets. Individual raw scores ranged from 43 to 76 out of a possible total of 90 on the three tasks. Individual raw scores for the analogy sets varied from 12 to 28 of a possible 30 points.

Eighth Graders' Performance

The eighth graders' mean scores for the three analogy sets were: (1) 22.46 for the Word Set, (2) 24.14 for the Picture Set, and (3) 25.24 for the Figure Set. These means indicate a fairly high degree of accuracy by the eighth graders on the analogy tasks. Their performance

appears to have steadily improved from words, to pictures, to figures showing the highest mean score. This trend paralleled that of the fifth graders. On the total experimental task, individual raw scores ranged from 53 to 81 points out of 90 possible. A range of 15 to a perfect 30 was calculated for the raw scores on the analogy sets.

Scores received by the female student currently enrolled in Special Education were as follows: (1) 19 for the Word Set, (2) 21 for the Picture Set, and (3) 20 for the Figure Set. These results were below the mean scores obtained by the fifth graders (i.e., 20.16 for the Word Set, 22.47 for the Picture Set, and 23.22 for the Figure Set); thus, her scores were similar to those of students a couple of years younger. This student also differed from the trend of difficulty exhibited by the fifth and eighth graders by showing a lower performance for figure analogies than picture analogies.

Eleventh Graders' Performance

The eleventh graders' mean scores for the three analogy sets were: (1) 24.13 for the Word Set, (2) 25.69 for the Picture Set, and (3) 25.45 for the Figure Set. Thus, a high degree of accuracy was demonstrated by the eleventh graders. Similar to the fifth and eighth graders, the eleventh graders achieved the lowest mean score on the word analogies, but their scores for the Picture and

Figure Sets were essentially equivalent. Individual raw scores ranged from 45 to 83 out of a possible 90 points. A range of 12 to 30 out of a possible 30 points was calculated for the raw scores on the analogy tests.

In order to explore further the differences among the three grades, simple effects of each independent variable (grade and modality) at each level of the other were tabulated. Results may be seen in Table 5.

Table 5
Simple Effects of Each Variable (Grade and Modality)
at Each Level of the Other

Effect	MSn	DFn	DFe	MSe	F	p
A at D1	248.12	2	193	5.14	48.25	.000
A at D2	161.35	2	193	7.10	22.72	.000
A at D3	94.61	2	193	5.70	16.61	.000
D at A1	173.22	2	386	4.08	42.51	.000
D at A2	129.99	2	386	4.08	31.90	.000
D at A3	54.17	2	386	4.08	13.29	.000

Note. A = Grade; D = Modality; D1 = Word Set; D2 = Picture Set; D3 = Figure Set; A1 = 5th grade; A2 = 8th grade; A3 = 11th grade;

Word Analogies

On the Word Set, the eleventh graders' mean performance of 24.13 was 1.67 points better than the eighth

graders' mean of 22.46 and 3.97 points better than the fifth graders' mean of 20.16. It was found that the three grades differed significantly from one another at the .001 level on the word analogies.

Picture Analogies

On the Picture Set, the eleventh graders' mean performance of 25.69 was 1.55 points better than the eighth graders' mean of 24.14 and 3.22 points better than the fifth graders' mean of 22.47. Simple effects showed that the performance of the three grades on the picture analogies was significantly different at the .001 level; therefore, the groups differed from one another on this task.

Figure Analogies

Lastly, on the Figure Set, the eleventh graders' mean score of 25.45 was only .21 points higher than the eighth graders' mean score of 25.24 but was 2.23 points higher than the fifth graders' mean of 23.22. The performance of the three grades on the figure analogies was reported as significantly different at the .001 level by simple effects but the difference appears to have occurred only between the performance of the fifth graders and the eighth or eleventh graders, not between the eighth and eleventh graders.

Relative Difficulty of the Three Modalities

The significant main effect for modality made it appropriate to analyze further the varied difficulty of the three analogy sets. No hypotheses were proposed concerning differential performance on the various modalities prior to testing. A pairwise comparison using the Newman-Keuls procedure for post hoc analysis was used to further investigate the relative difficulties of the three analogy sets (see Table 6).

Table 6
Newman-Keuls Pairwise Comparison of Modality

	Word	Picture	Figure
Word	X		
Picture	<.01	X	
Figure	<.01	<.05	X

Word versus Picture Analogies

A pairwise comparison of modality using the Newman-Keuls procedure indicates a significance at the .01 level between word and picture analogies across the three grades. Therefore, it is known that word and picture analogies differed significantly from one another overall, and that words were more difficult, although it is not

known where the significance occurred (i.e., in the fifth, eighth, or eleventh grades or all of them). See Figure 1 for a visual representation of the mean score differences between grades and modality types.

Picture versus Figure Analogies

Post hoc analysis indicates a significant difference between picture and figure analogies at the .05 level. In the eleventh grade, the mean score for figure analogies dropped for the only time below that of the picture analogies although the difference was only .25 points. The essentially equivalent scores for the picture and figure analogies at the eleventh grade may explain why the level of significance between picture and figure analogies was at the .05 level whereas the level of significance between the other modalities was at the .01 level. Again, it is not known which of the grade levels represent this significance.

Word versus Figure Analogies

Post hoc analysis using the Newman-Keuls procedure revealed a finding parallel to those yielded by the preceding pairwise comparisons. There was a difference at the .01 level of significance between the word and figure analogy tasks, with word analogies the more difficult.

Interaction Effect for Grade and Modality

The relative difficulty of the three modalities for each of the grades may be seen in Figure 1. As discussed above, it is known that a significant difference exists between the grades on the three modality tasks and that the analogies differed significantly from one another across the three grades; furthermore, the ANOVA table revealed that there was a significant interaction between grade and modality, which indicates that the grades experienced the task difficulty differentially. However, it is not known precisely how task difficulty contributed to the significant differences in mean scores within each grade (e.g., Was there a significant difference between word and picture analogies in the fifth grade, or between picture and figure analogies in the eleventh grade, and so on).

The statistical program used for this study, CLR ANOVA, did not permit pairwise comparisons on those two variables (grade and modality). Therefore, the Bonferroni method of post hoc analysis was pursued as a possible means for investigating the differences between modality scores within each grade level. It is a method of multiple comparisons which may be used with analysis of variance models. Due to the fact that the current study is a four-way repeated measurement design and the Bonferroni

method is typically used with one-way repeated measurement designs, the task of deriving the necessary statistical procedures became extremely complicated. As a result, it was decided that the complexity of the statistical treatment required would have outweighed the value of the information to be gained. As can be seen in Table 7, the point differences between the modalities at each grade were quite small and in fact, the largest difference noted was 3.07 points between figure and word analogies at the fifth grade level. A difference of one, two, or even three points between modalities would not be regarded as clinically significant although it may be statistically significant. Since the focus of this research was on obtaining information regarding treatment decisions, these differences were not pursued statistically.

Table 7
Point Differences Among Mean Scores

Modality	Grade		
	5	8	11
Picture - Word	2.31	1.68	1.56
Figure - Picture	.75	1.10	-.25
Figure - Word	3.07	2.78	1.56

Summary

To summarize the results of this study, significant differences were found for the main effect for grade, main effect for modality, and the interaction effect for grade by modality. Sex was not found to be a statistically significant variable. Nor was class nested within grade found to be a statistically significant variable. The Newman-Keuls procedure for post hoc analysis was used to investigate areas of significant difference.

The combined group means achieved by the fifth graders were lower than those of the eighth and eleventh graders and the group means achieved by the eighth graders were lower than those of the eleventh graders. Post hoc analysis revealed significant differences between the three grades' performance, which indicated that analogical reasoning skills do increase with age as hypothesized. Significant differences were also found between modality tasks; however, the differences calculated between mean scores when comparing two modalities was so small (i.e. 1-3 points) that further analysis was deemed unnecessary.

CHAPTER V

DISCUSSION

The results of this study showed the groups to perform significantly differently from one another on analogical reasoning tasks involving three modalities. Significant differences were found for the grade effect, the modality effect, and the grade-by-modality interaction effect. The significance for the grade effect indicates significant differences among the three grades on the experimental task. The significance for the modality effect indicates differences among the three sets of analogies. Finally, the significant grade-by-modality interaction effect indicates that the three tasks were experienced differentially by the three subject groups.

Differences Among the Three Grades

A significant difference was found among the three grades indicating that their performance on the task was not alike. Furthermore, post hoc analysis revealed a significant difference between each pair of adjacent grades, thereby confirming the initial hypothesis that analogical reasoning skills increase with age. This developmental trend has been demonstrated by a number of studies (Gentner, 1977; Holyoak et al., 1984; Levinson & Carpenter, 1974; Sternberg & Nigro, 1980).

A consideration for future investigations based on these findings is that the classes tested at each grade level may not have been comparably heterogenous. The school district in which the testing was conducted engages in performance placement of the students. Therefore, students of similar abilities are placed together in classrooms. To take this variation into account, an attempt was made to test classrooms at each grade level which contained students of above average, average, and below average abilities. In such a situation, it is difficult to ensure that the overall configuration of each grade is equivalent to that of the others. Examination of the group data does not evidence any gross difference among grades, so in all likelihood the distribution of students at each grade was similar. In addition, the lack of significance found for class nested within grade indicates that there was no significant difference between classes. Further investigations in this area would need to control for these variations in subject populations.

Differences Among the Three Analogy Sets

In addition to the differences between the grades on the analogy tasks, differences were assessed on the three types of analogies within groups. Significant differences were found when comparing the three sets of analogies with

one another, revealing that the three analogy tasks were not equivalent in difficulty. Examination of the mean scores for the three modalities showed that the lowest scores were obtained for the word analogies at all three grades, followed by picture analogies and then figure analogies.

Although significant differences were found for the grade-by-modality interaction, a difference of only one to three points was found when comparing scores between modalities. One of the experimental questions asked by this study was whether fifth, eighth, and eleventh graders perform better on one type of analogy as opposed to another. As discussed above, it is known that a difference exists and that the direction of the difference is demonstrated by the mean scores of each grade. It is known that words are harder than picture or figure analogies and that figure analogies are the easier than picture and word analogies except at the eleventh grade level, where performance on figure analogies appears to have hit a plateau with very little difference between picture and figure analogies. What is not known is if the differences in the scores for two modalities (e.g., picture and word analogies) are significant within the individual grade levels. Given the minor point differences noted between the mean scores on the analogies, clinical significance was not demonstrated. Thus, no further analyses were conducted.

The possibility of order effects must be considered since the order of presentation of the modalities was word analogies, followed by picture analogies, followed by figure analogies, which corresponds to the trend of increasing difficulty for the analogy types. A practice effect may have occurred, causing the subjects' performance to increase with each succeeding modality. I.e., since word analogies were presented first, they may have been more difficult due to lack of practice. By the time the figure analogies were presented, the subjects would have had plenty of practice in solving analogies. A practice effect of this type would make it difficult to conclude that one modality was more difficult or easier than another. On the other hand, the likelihood of this kind of order effect is weakened by the fact that the analogies were presented in three sets of word, picture, and figure analogies rather than all of the word analogies first, followed by all of the picture analogies, then all of the figure analogies.

Another consideration for the minimal differences observed when comparing performance on the three modalities is that the three analogy sets might not have been equal in their measurement of cognitive functions. For example, the items selected for the Word Set might have been more difficult than those selected for the Picture Set. In support of this idea is the fact that all three

grades achieved lower mean scores on the word analogies than the pictures. Or perhaps the scales of difficulty were not commensurate with one another. For example, picture and word analogies from Level C might have been difficult analogies, but the figure analogies from Level C might have been relatively easier.

It is difficult to ensure that the analogies at each level are equivalent to one another in difficulty because of the differing concepts used in each set to increase item difficulty. For instance, word analogies may increase in vocabulary level and the complexity of the analogous relationship. In addition, words may represent abstract concepts which pictures and figures cannot. Picture analogies are limited by the necessity to represent the concepts in a drawing and they are therefore necessarily concrete. Figure analogies may increase in complexity by using a variety of different transformations such as shading, mirroring, and adding or subtracting elements. Complexity increases as the number of transformations utilized within a problem increases. The information provided in Appendices E and F has a bearing on the question of relative difficulty of the items in the three modality sets. Appendix E provides the proportions of students answering each item correctly, averaged across the three classes within each grade. Appendix F shows the mean proportions within each level of difficulty, along

with standard deviations. Examination of Appendix F reveals that performance decreased across the grades with each succeeding level of difficulty. This would seem to indicate that the levels of difficulty were fairly equivalent across the three modalities.

Another possibility is that the drawings for the picture analogies did not accurately represent the intended analogical relationships. If that was the case, then the Picture Set may have been more difficult to complete than the Word or Figure Sets. The possibility also exists that the relationships expressed by the geometric designs in the figural analogies may have been improperly drawn.

After subjects were tested, they were asked by the examiner which type of analogies they found most difficult. At all three grades, approximately half of the class responded by saying that the word analogies were most difficult and the other half responded that the figure analogies were most difficult. Very few individuals indicated that the picture analogies were difficult. In fact, when asked the majority of the students said they were easy. Interestingly, the students' comments were not reflected in their scores. The mean scores for word analogies were the lowest, but the figure analogies represented the highest mean scores over all three grades.

In order to investigate these above mentioned possibilities, an item analysis of all analogies which were solved by fewer than 50% of the students in all nine classes (three classes per grade) was conducted. This analysis will be discussed in the following section.

Individual Analysis of Difficult Analogy Items

Item analysis revealed that there were 14 analogy problems (6 word, 3 picture, 5 figure) that were consistently answered incorrectly by over half of the subjects in each of the nine classes. Thirteen of these analogies were at Level C, which was designed to contain the most difficult problems. The fourteenth item was a picture analogy at Level B which will be discussed below.

Word Analogies

Six of the word analogy questions at Level C were missed by over 50% of the subjects. An examination of the six items reveals that the analogical relationships are correctly represented by the terms and that the solutions are unambiguous. The vocabulary used in these items is more difficult than that used at Levels A and B and the analogical relationships represented are also more difficult (Nelson & Gillespie, in press). The analogy "remedy is to fix as destroy is to ?" (return, undo, retard) should be answered "undo" however, when comparing scores

from the nine classes tested, a range of only 0 to 27% of the subjects answered it correctly. Interestingly, the eleventh graders performed the worst with only 0 to 4% of them answering correctly.

Another frequently missed item was "snake is to cobra as human is to ?" (eskimo, person, mammal) with the correct answer being "eskimo." When looking at performance in each of the nine classes, class scores ranged from 0 to 13% of the subjects answering correctly. The vocabulary level of this analogy is not difficult but the analogical relationship is complex. In order to ascertain the correct relationship, an individual must be familiar with the scientific classification system for organisms. A cobra is a type of snake just as an eskimo is a type of human.

A simple antonymous relationship was expressed by the analogy "important is to negligible as recognized is to ?" (ignored, uncovered, believed)" with "ignored" as the correct answer. Four to 17% of the subjects answered correctly. Similarly, "Wax is to wane as advance is to (retreat, approach, find)" was answered correctly by 4 to 47% of the subjects. It is possible that subjects had difficulty with this analogy because of the relative obscurity of the terms "wax" and "wane." These words are often paired together but are not commonly used.

Another commonly missed item was "retained is to relic as novel is to (innovation, saved, fiction)." The answer is, of course, innovation. Percent correct scores in the classes ranged from 7 to 48%. Finally, the analogy "nibble is to bite as quibble is to (object, release, quirk) requires the answer "object." This item is complicated by the fact that the correct answer "object" may represent a verb or a noun. This factor may have played a role in the difficulty of the question since two different interpretations may be placed on the word. A range of 0 to 48% correct was noted for this question. The highest score was obtained by an eleventh grade class, while the lowest score was obtained by a fifth grade class. This result is to be expected considering the finding that analogical reasoning abilities improve with age. None of the analogies discussed above appears to be ambiguous in any way or improperly written. It is still possible that the Word Set simply had more difficult items than the other two sets which led to lower overall scores on the word analogies.

Picture Analogies

Only three of the picture analogies were missed by over 50% of the subjects within each class. (These analogies may be seen in Appendix G.) One was at Level B while the other two were Level C analogies. A problem

unique to picture analogies is that they lend themselves to a greater variety of interpretations because the analogical relationship must be depicted through a drawing. Two individuals may see the same drawing as depicting totally different concepts. For instance, referring to picture #1 in Appendix G, a judge is pictured sitting at his desk and then pounding his gavel. These two pictures represent the terms "A" and "B" in the analogy. The third picture (i.e., "C" term) depicts a clergyman standing at a pulpit. The possible solutions to this analogy are (1) a Bible, (2) a clergyman raising his arms, and (3) a cross. When a class of eleventh graders was informally asked what the correct answer was supposed to be, they were divided in thirds as to their choice. The correct answer should have been choice two, the clergyman raising his arms because that is how he gets his congregation's attention just as the judge gains the courtroom's attention by pounding his gavel. The clergyman's raising his arms may also be considered a characteristic gesture just as pounding a gavel is a gesture characteristic of a judge. Also, the analogical relationship between the first two pictures involved an action; therefore, the answer chosen must involve an action. A problem noted with this item is that it is culturally biased. Many of the students commented upon the fact that the religious leaders in their religions do not use hand gestures such as the one depicted.

Some individuals thought the clergyman was blessing someone rather than trying to gain attention. Even if this were the case, the appropriate answer would still be choice two because blessing someone with raised arms is still a characteristic gesture.

The item at Level B which was missed frequently posed a problem in that subjects needed to know that the ant pictured was a carpenter ant (See Appendix G picture #2). Once it was ascertained what type of ant it was, the answer was obvious. The carpenter ant gets food (wood) from the log just as the bee gets food (pollen) from the flowers. This problem derives its difficulty from the fact that the subject's world knowledge is really put to the test in trying to determine the type of ant pictured. If that fact was not known, then any of the answer choices would seem to be appropriate. This item proved to be the most difficult for fifth and eighth graders who answered within a range of 15 to 27% correct. In actuality, many of the eleventh graders stated that they knew the picture was of a carpenter ant and answered accordingly. The eleventh graders range of accuracy was 34 to 68%.

The final picture analogy represents a problem with the drawings. In this case, the upper left picture was supposed to represent a river but instead may be mistaken for a trail or path. In addition, a mistake was made and the bottom left hand picture of the leafless tree (i.e.,

the "C" term) was transposed with answer choice #3. Only 11 to 45% of the students picked the answer which was considered the best choice under the circumstances.

A fourth picture analogy will be discussed not because less than half of the subjects answered it correctly, but because the features represented were not drawn adequately. It provides a good example of the effects of inadequately drawn pictures on the ability to solve analogies. Two problems exist with this analogy: (1) the drawing of the church may be mistaken for a courthouse, and (2) the second choice out of the three answers is supposed to be a barn but it is inadequately drawn. Obviously, such ambiguity in the drawings would lead to difficulty in answering this question properly.

The difficulties experienced with a few of the picture analogies may have had an effect upon the scores of the subjects. If these pictures had been adequately drawn to depict the intended features of focus more clearly, subjects might have obtained better scores on the picture analogies. Also, there may be other pictures which posed difficulties for certain individuals based upon their unique interpretation of them. In this sense, picture analogies may be harder than word analogies. Words often have multiple meanings but those meanings are essentially the same across individuals.

Figure Analogies

Five of the figure analogies posed difficulties for the subjects. These analogies may be seen in Appendix H. Examination of the analogies exposes the fact that all of them but one require mental rotation for their solution. The one analogy not requiring mental rotation instead requires the addition of elements to the initial design. The complexity of these items is derived from the number of transformations occurring. Instead of one or two transformations, their solutions involve three or four different manipulations by the subject, such as rotating two different parts of the figure in different directions and then removing the shading from part of the figure. Although these figures are complex, none of them is incorrectly drawn. Due to the high performance on figure analogies, it is apparent that subjects had the least amount of difficulty with them out of all of the analogies. The possibility exists that the figure analogies were too easy and were not as challenging as the words and pictures. However, when asked, the subjects seem to feel that the word and figure analogies were equally difficult. In addition, the table in Appendix F seems to indicate that the levels of difficulty are consistent for each of the analogy types.

Clinical Implications

Analogical reasoning abilities do appear to increase with age as far as fifth, eighth, and eleventh graders are concerned. The ability to process analogies has been proposed to be a measure of intelligence (Spearman 1927; Sternberg & Nigro, 1980). Analogical relationships are derived by individuals every day in order to problem solve by comparing past events to current events. In light of these facts, diagnosis and treatment of individuals with impaired analogical reasoning abilities should be undertaken. In order for this to occur, diagnostic tests sensitive to deficits in analogical processing must be developed. Achenbach (1969) developed the Matching Familiar Figures Test which was designed to differentiate children who are associative versus nonassociative responders. The Learning Potential Assessment Device was devised by Feuerstein (1979) as a means of assessing the cognitive abilities of retarded performers. Verbal analogical reasoning may be used as a technique for identifying children with mild to moderate linguistic deficits (Nippold, 1986). These individuals may be passed over because available standardized tests are not sensitive enough to detect mild deficits.

A variety of techniques may be used to facilitate the improvement of analogical reasoning abilities. Workbooks

and computer programs are available which guide the teacher and student in solving analogies (Black & Black, 1986, 1987a, 1987b, 1988; Tomlin, 1986). Feuerstein (1979) found that it was possible to improve the cognitive abilities of retarded performers using analogical reasoning tasks. Therefore, it may be possible to alter cognitive abilities in other impaired populations such as language disordered, learning disabled, and the hearing impaired.

In this study, a significant effect was found between the three modalities indicating that they were experienced differentially by the subjects. The overall mean scores for each grade differed by only one to three points when comparing two different modalities. This was not considered a clinically significant difference. It would be erroneous on the part of a clinician to arbitrarily decide to begin work on picture analogies because a child answered three more picture analogies correctly than he did word analogies. To begin work with an individual client on a specific modality on the basis of mean group performance would be an even greater error.

This study was limited statistically to examining group performances rather than individual performances. While the overall mean scores within each modality did not differ widely, it is interesting to note the wide variance in individual scores. For instance, a male in the fifth

grade received the following scores: 19 for the Word Set, 22 for the Picture Set, and 27 for the Figure Set. This range is similar to that obtained for the entire fifth grade although this student exhibits a larger gap between the word and figure analogies. Another male in the same class received these scores: 22 for the Word Set, 27 for the Picture Set, and 20 for the Figure Set. This student appears to have performed better on the picture analogies than the figure analogies, in contrast to the trend for the fifth grade.

A possible explanation for these results is that each of these students exhibits strengths in different areas. According to Gardner (1985), individuals may express strengths in any of seven intelligences. If this is true, the first student may be said to be exhibiting a strong visual-spatial intelligence because of this strong performance on figure analogies. These individual patterns would seem to present a case for the necessity of assessing each individual's strengths and weaknesses rather than assuming a general rule for all individuals on the basis of overall group trends. This is especially true in the case of impaired individuals. The wide variance in scores exhibited by normal children may be even more exaggerated in impaired individuals such as language disordered children. The administration of pretests utilizing multi-modality analogies prior to treatment may help a clinician

determine in which, if any, of the modalities a client shows a strong performance. Such information may help suggest an appropriate modality with which to begin therapy.

Recommendations for Future Research

Problems in the design of the current study may be addressed by using better constructed analogies which represent a wide range of difficulty for the subjects. Fifth graders were chosen as the youngest group in this study on the basis of evidence suggesting that the ability to solve analogies in the form A is to B as C is to D is not well developed until a child is eleven to twelve years old (Levinson & Carpenter, 1974; Holyoak et al., 1984). This study confirms the belief that analogical processing abilities are developed by at least the age of eleven. A consideration for future studies may be to use even younger subjects in an attempt to further investigate the acquisition of the skills necessary for solving analogy problems in this form. A span of three school grades between each of the groups was arbitrarily set in order to ensure a significant difference in ages between the groups. Assessment of analogical processing abilities at each grade level may lead to more information regarding developmental trends.

An interesting variation on the current study would be to investigate the apparent plateau observed for figure analogies at the eighth and eleventh grades. One possible way to investigate the plateau would be to train students in both grades in the rules and strategies underlying figure analogies while a control group for each grade would receive no training. If none of the groups' performance improved after retesting, then the groups would evidently be experiencing a true plateau in the ability to solve figure analogies. However, if only the eleventh graders who underwent training improved in performance, then apparently training would be effective for more mature subjects but not the less mature eighth graders. They would not be able to process the stimuli at a higher cognitive level yet.

Cognitive abilities are believed to decline after age 60 (Schaie, 1983); therefore, a study of analogical reasoning skills in geriatric populations would be of interest to determine if they decrease and if so, to what degree. Information provided by such a study would be useful in the treatment of stroke victims since the majority of victims are elderly.

Analogical reasoning abilities in language disordered and learning disabled individuals is an area which is in great need of further research. A study comparing how normal children versus language disordered children solve

analogies could be conducted by asking subjects to discuss each step they go through to reach the solution. Information from a study of this nature might help determine where language disordered children fail in their attempts to reason analogically. Research is needed especially in the area of therapeutic intervention. Case studies describing successful techniques for increasing analogical reasoning abilities will provide clinicians with valuable clinical information.

Conclusions

This study was designed to investigate analogical processing abilities in fifth, eighth, and eleventh grade students. Multi-modality analogy tasks were used. The conclusions that can be drawn from this study are as follows:

1. Analogical processing abilities, as measured by the tests used in this study, improve with age across the fifth, eighth, and eleventh grades.
2. Word, picture, and figure analogies are experienced differentially by fifth, eighth, and eleventh graders.
3. Males and females in the fifth, eighth, and eleventh grades do not perform differently from one another on word, picture, or figure analogies.

Appendices

Appendix A
Informational Letter Sent to Parents

Informational Letter Sent to Parents

Dear Parents:

Your child's class has been selected to participate in a study of analogical reasoning skills in 5th, 8th, and 11th grade students. Analogical reasoning skills are commonly tested in the schools. An example of an analogy problem would be the question, "bird is to fly as fish is to ?" The correct answer would be "swim." The information obtained from this study will be used to determine how analogical reasoning skills develop in children and will lead to the development of improved methods for teaching analogical processing skills to students.

Any information provided to the investigator will be kept strictly confidential. Students' names will not be used at any time during this study since all information is collected anonymously. Your child's involvement in this study would consist of participating for a period of 45-50 minutes in his or her regular classroom. The school's superintendent, Mr. Weeldreyer, and principal, Mr. VanDoeselaar, have been consulted about this project and have agreed to allow me to test students pending parental consent. You have the right to withdraw your child from this study at any time and your child will be given that same option prior to testing in the classroom. If you or your child decide that you do not wish to participate in this study, the student will be given a relevant assignment to do by the classroom teacher while the other students are participating. If you have any questions about your child's participation in this study, please feel free to send a note to the school or call regarding your concerns. If you decide that you do not want your child to participate in this study, please contact the student's teacher at the school (668-3361) prior to the date of testing which is October 10.

If you have any further questions regarding your child's participation in this study please feel free to contact me.

Amy S. Cashen
Graduate student
Department of Speech Pathology and Audiology
Western Michigan University
Home 327-7424 Campus 387-8045

Appendix B
Confirmation Letter From HSIRB Stating
Approval of Research Protocol

WESTERN MICHIGAN UNIVERSITY

Date: September 20, 1989

To: Amy Cashen

From: Mary Anne Bunda, Chair *Mary Anne Bunda*

This letter will serve as confirmation that your research protocol, "Analogical Processing Skills in 5th, 8th Grade, and 11th Grade Students in Three Modalities", has been approved by the HSIRB. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the approval application. You must seek reapproval for any change in this design.

The Board wishes you success in the pursuit of your research goals.

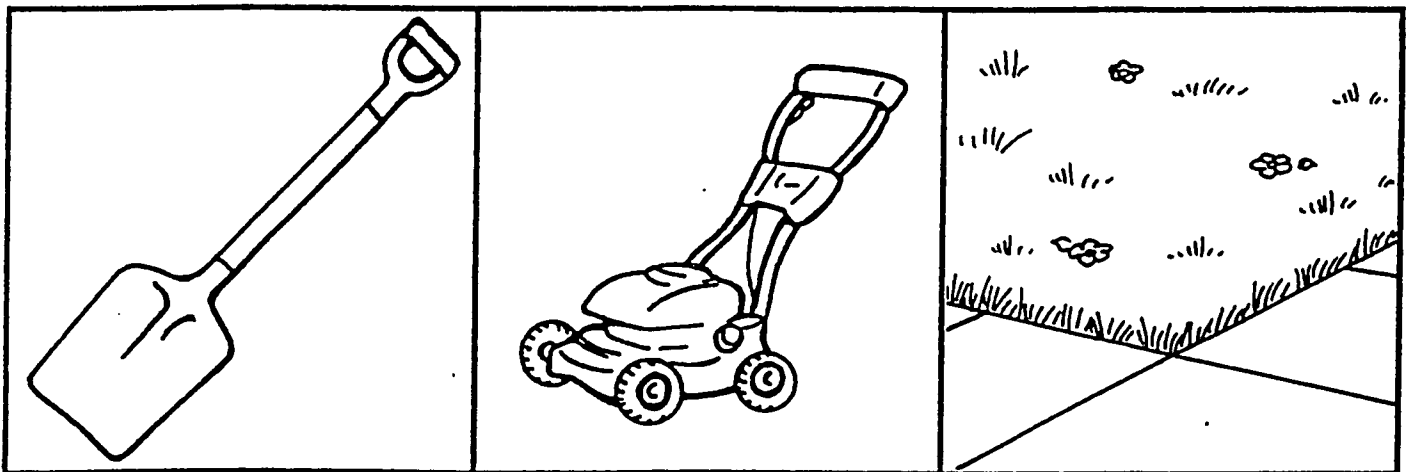
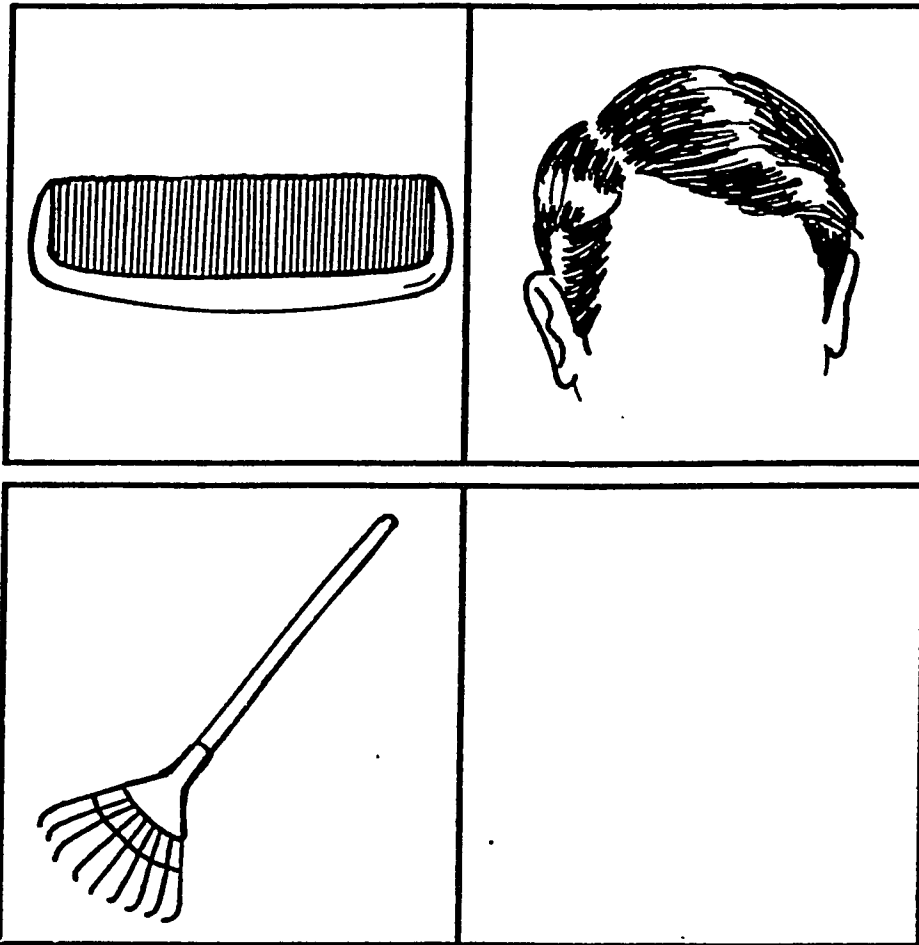
xc: M. Clark, Speech Pathology and Audiology

Appendix C
Examples of the Three Analogy Sets

apple	fruit
cat	

dog	furry	animal
1	2	3

Example of a Picture Analogy

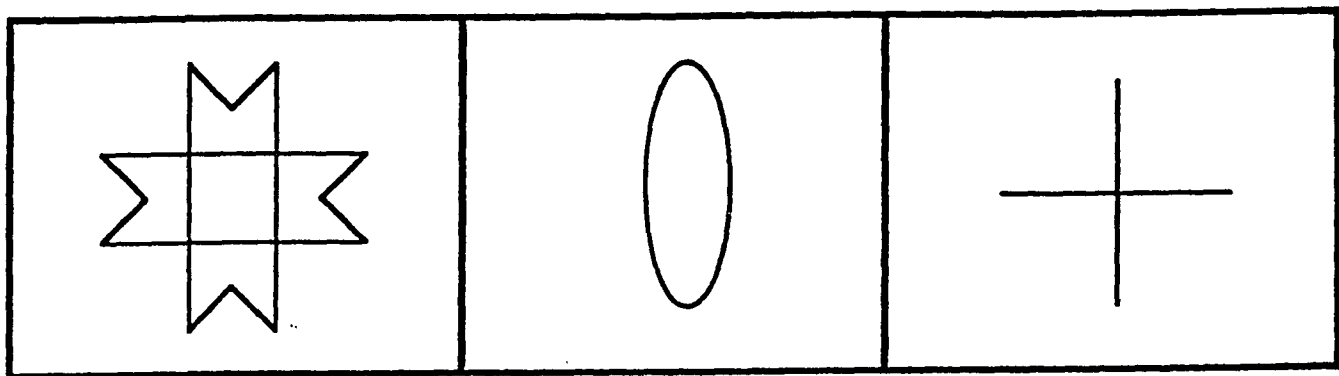
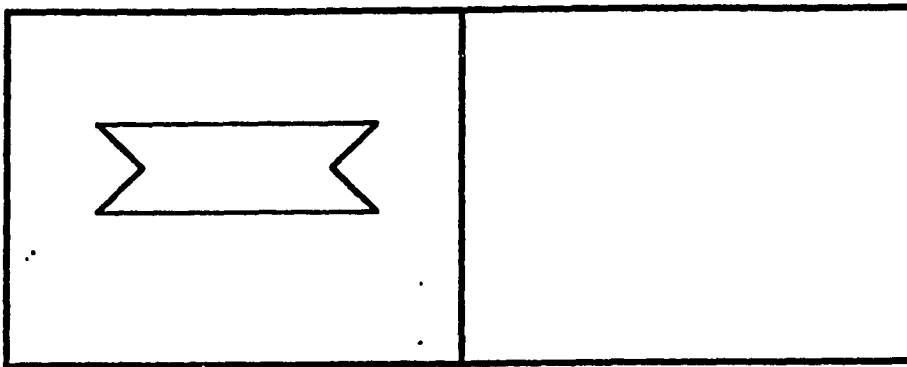
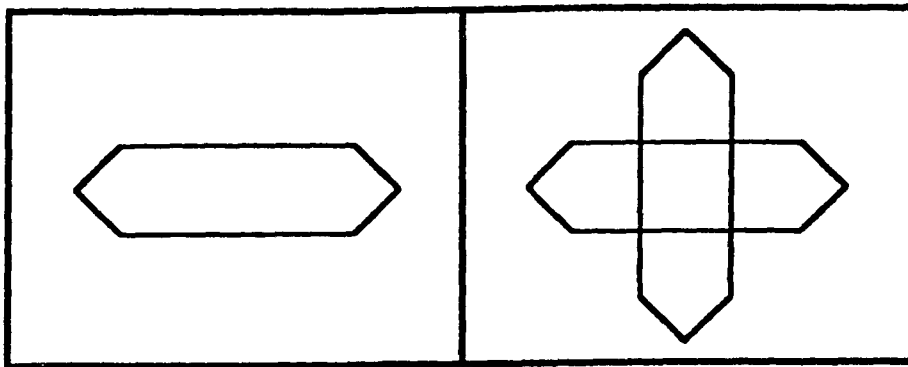


1

2

3

Example of a Figure Analogy

**1****2****3**

Appendix D
Dialogue Used by Examiner During Testing

Dialogue Used by the Examiner
During Testing

Hello, my name is Amy Cashen. I am a graduate student at Western Michigan University. I am here today because I need your help with a research project I am involved in at Western. I am studying students' ability to solve analogies in the 5th, 8th, and 11th grades. Many of you have probably taken tests before which have analogy problems such as "bird is to fly as fish is to what?" Swim would be the correct answer because a bird flies in order to get around and a fish swims to get around.

Today, I am asking you to solve some analogies for me. Before we begin, I want to explain that these tests will not be graded nor will your name ever be used outside this classroom. You have the right to refuse to participate if you want to at any time before or during the test without penalty. By penalty, I mean that your class grade or class participation grade will not be affected by your deciding not to take the test. If you decide not to participate, please work quietly at your desk. (Answer sheets and pencils are passed out.)

I want everyone to write your birthdate in the section called "Date" on the answer sheet. Please fill it in just as I have on my sheet (shown on the overhead). Please do not write your name anywhere on the sheet. Also, at the bottom of the sheet on the line that says "Instructor" please write down your sex - M for male and F for female. You might have used these answer sheets before, but let me go over the instructions quickly. It is very important that you completely fill in the answer circle without going outside the edges. It is okay to erase but make sure you erase the old mark completely. Also, please check frequently to make sure that you are on the right question number. I will announce each question number as we go. I am going to put each question up on the overhead for a certain amount of time. When that time is up, I will say "Pick your answer, please." You will then have a couple of seconds to choose your final answer. If you are not sure of an answer just do the best that you can and make a guess. Please look at each question carefully and use all of the time available. Are there any questions?

Appendix E

**Proportion of Students Answering Correctly on
the Modality Task Items by Grade and
Level of Difficulty**

**Proportion of Students Answering Correctly on the
Modality Task Items by Grade and
Level of Difficulty**

	Words			Pictures			Figures		
	5th	8th	11th	5th	8th	11th	5th	8th	11th
Level A									
1.	.79	.87	.97	.67	.92	.91	.96	1.0	.98
2.	.70	.79	.87	.84	.98	.95	.92	1.0	.93
3.	.81	.90	.91	.94	1.0	.97	.88	.97	.94
4.	.86	.93	.94	.81	.92	.97	.93	.97	.94
5.	.61	.76	.94	.94	1.0	.97	.86	.96	.94
6.	.96	.96	.96	.77	.87	.92	.95	.95	.98
7.	.84	1.0	.95	.84	.92	.93	.80	.81	.78
8.	.92	.96	.95	.67	.84	.92	.96	1.0	.98
9.	.96	.98	.98	.92	.93	.98	.62	.83	.88
10.	.71	.97	.97	.92	1.0	.93	.92	.97	.97
Level B									
11.	.66	.80	.76	.99	1.0	.94	.42	.82	.74
12.	.27	.24	.52	.95	.97	.97	.20	.11.	.02
13.	.89	.97	.97	.82	.86	.80	.11	.04	.06
14.	.84	.89	.91	.86	.90	.90	.27	.80	.86
15.	.76	.76	.83	.67	.76	.64	.74	.80	.86
16.	.94	.96	.97	.68	.86	.85	.14	.32	.49
17.	.96	.95	.94	.95	.94	.97	.77.	.81	.91
18.	.63	.62	.71	.77	.97	.93	.59	.95	.91
19.	.61	.80	.90	.83	.92	.92	.16	.18	.31
20.	.96	.92	.94	.97	.98	.92	.07	.11	.27

Appendix--Continued

Words			Pictures			Figures			
5th	8th	11th	5th	8th	11th	5th	8th	11th	
Level C									
21.	.42	.82	.74	.90	.97	.94	.72	.62	.72
22.	.20	.11	.02	.59	.54	.59	.53	.70	.63
23.	.11	.04	.06	.16	.84	.86	.48	.60	.49
24.	.27	.19	.12	.66	.71	.67	.60	.61	.67
25.	.74	.80	.86	.13	.11	.17	.70	.82	.81
26.	.14	.32	.49	.87	.86	.82	.78	.84	.88
27.	.77	.81	.91	.84	.94	.93	.33	.64	.68
28.	.59	.95	.91	.30	.18	.38	.38	.49	.33
29.	.16	.18	.31	.76	.95	.82	.51	.77	.75
30.	.07	.11	.27	.55	.79	.90	.29	.52	.52

Appendix F

Mean Proportion of Correct Answers and Standard Deviations for Modality and Grade at Each Level of Difficulty

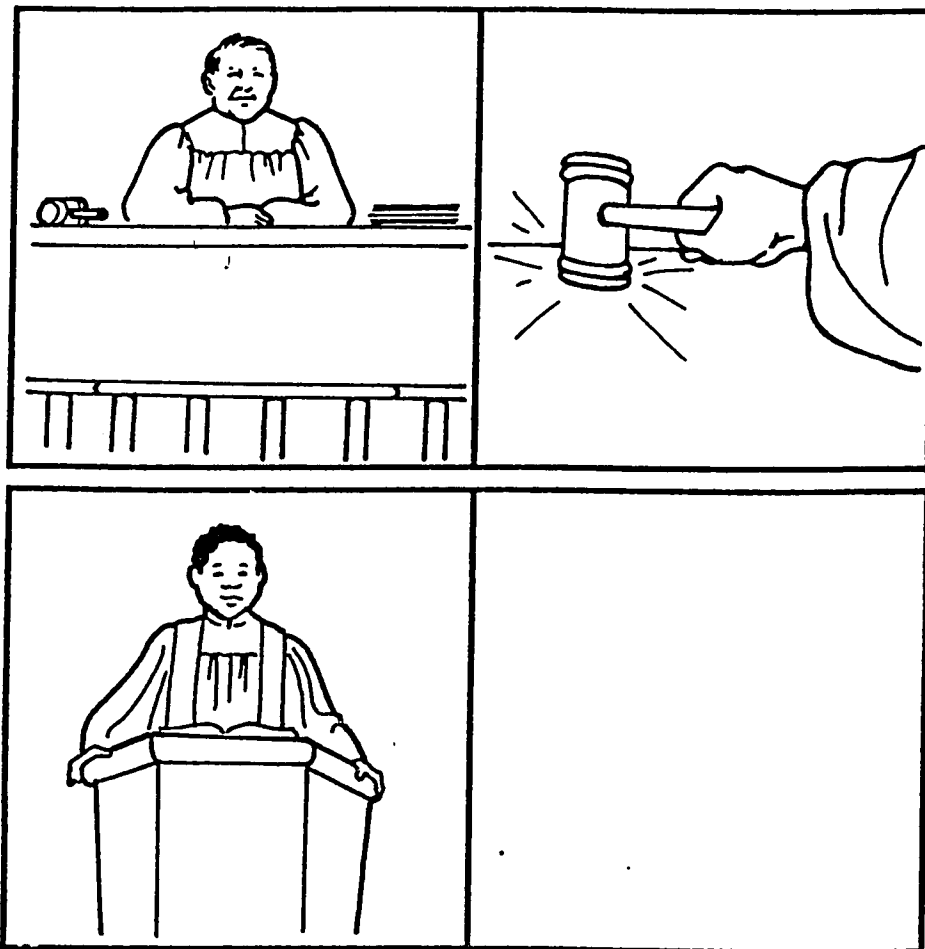
**Mean Proportions of Correct Answers and Standard
Deviations for Modality and Grade at
Each Level of Difficulty**

Words			Pictures			Figures			
5th	8th	11th	5th	8th	11th	5th	8th	11th	
Level A									
M	.82	.91	.94	.83	.94	.95	.88	.95	.93
SD	.12	.07	.03	.10	.06	.03	.10	.07	.06
Level B									
M	.79	.91	.93	.75	.79	.85	.85	.92	.79
SD	.15	.10	.08	.22	.22	.14	.12	.07	.13
Level C									
M	.35	.43	.47	.58	.69	.70	.54	.66	.65
SD	.27	.36	.36	.29	.31	.26	.17	.12	.16

Note. M = Mean Proportion; SD = Standard Deviation.

Appendix G

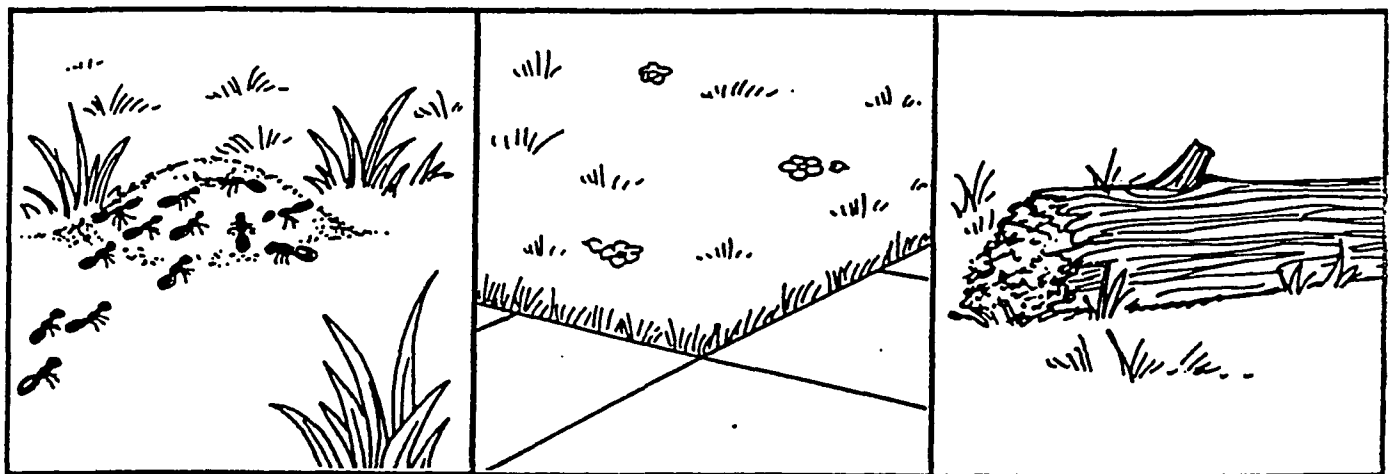
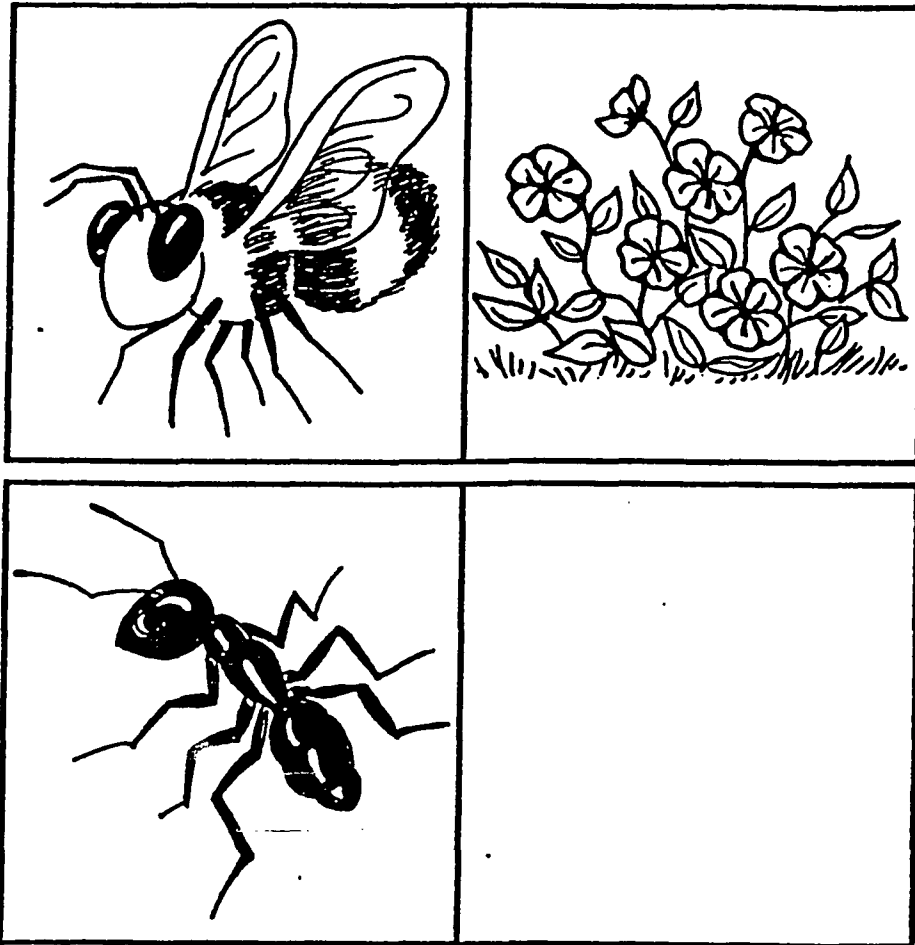
Picture Analogies Missed 50% of the Time



1

2

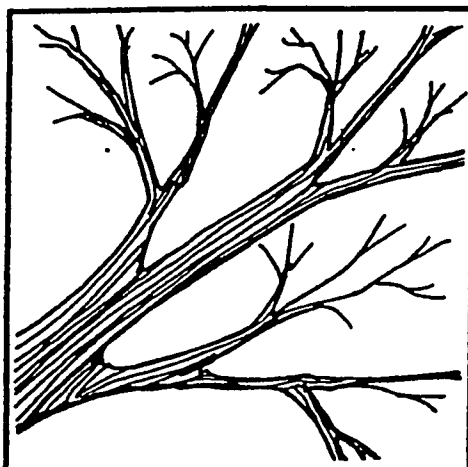
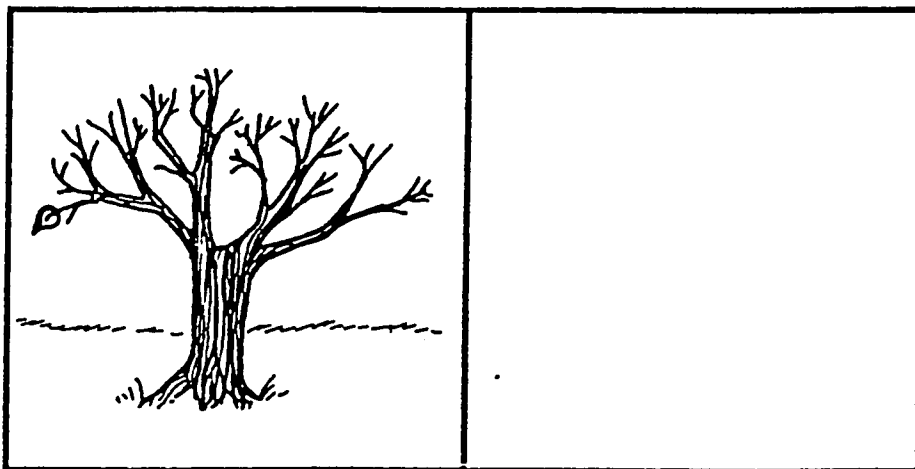
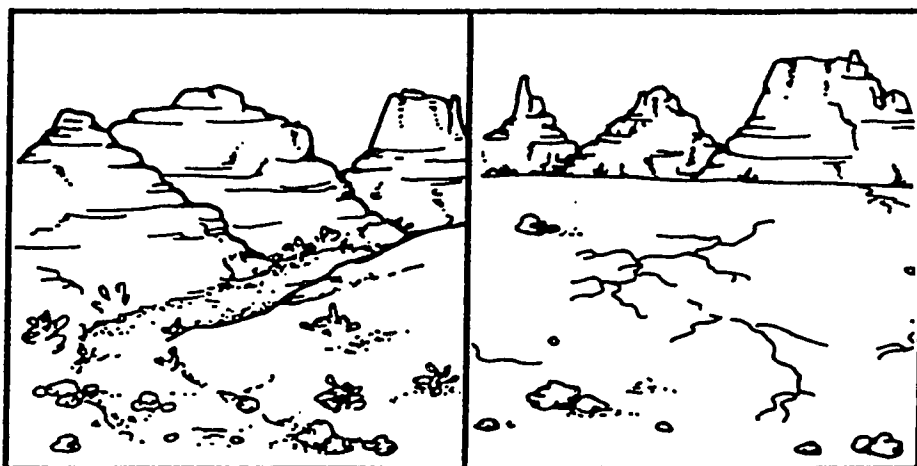
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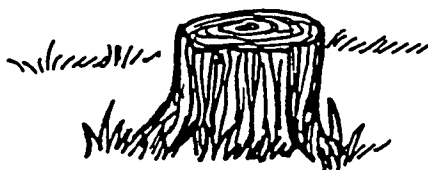
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2

3



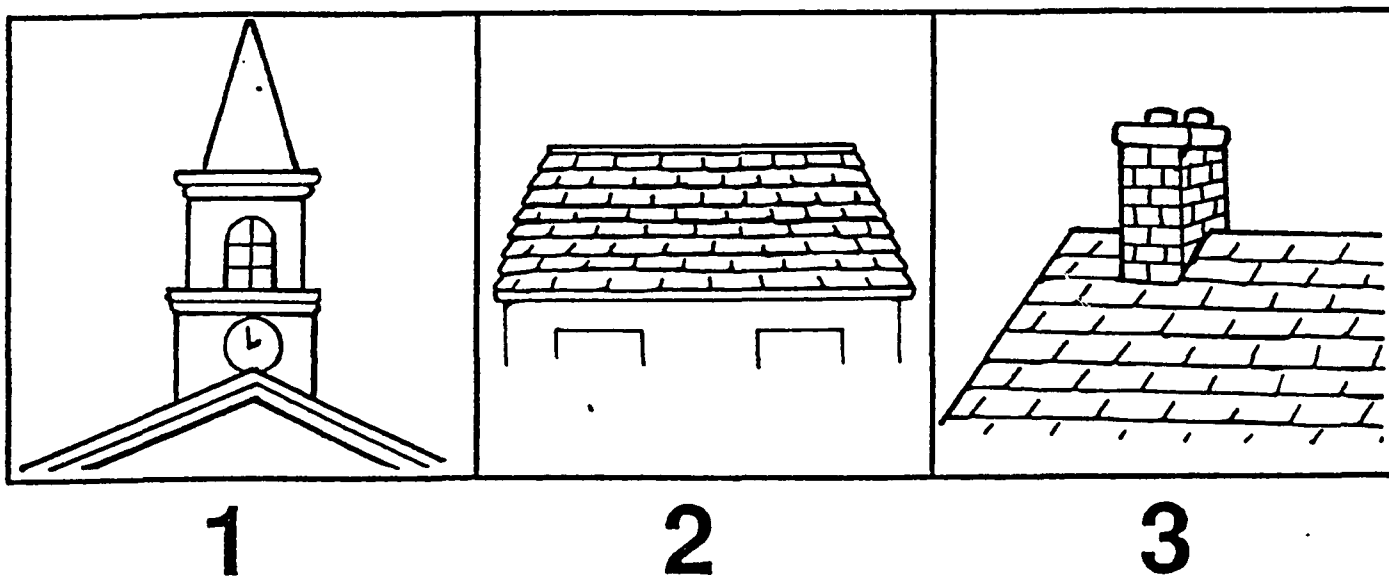
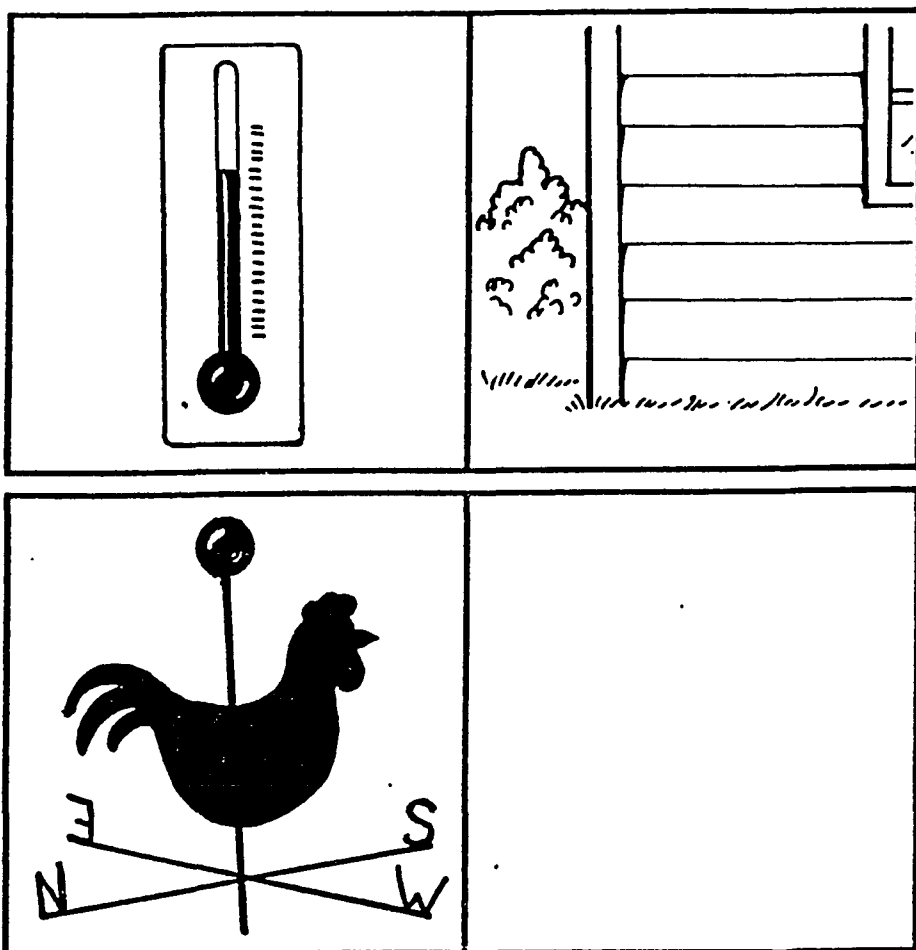
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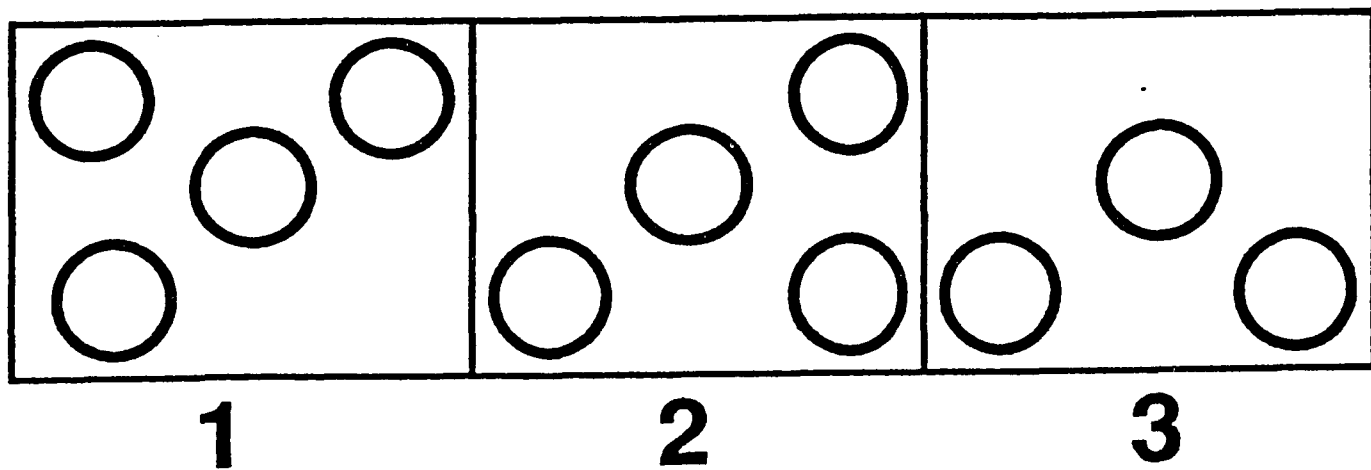
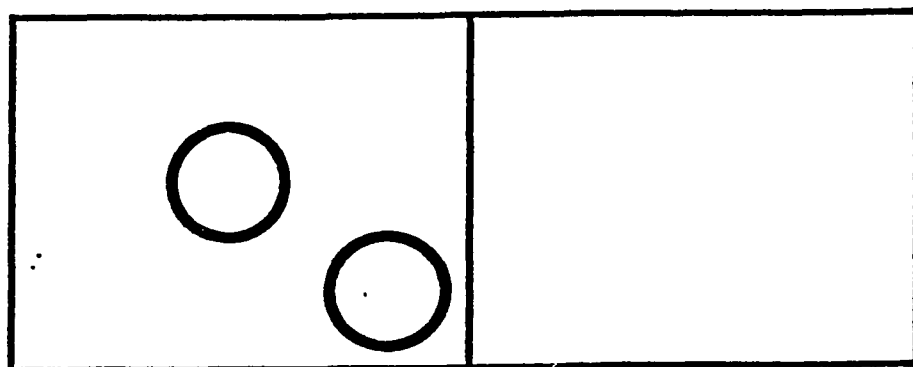
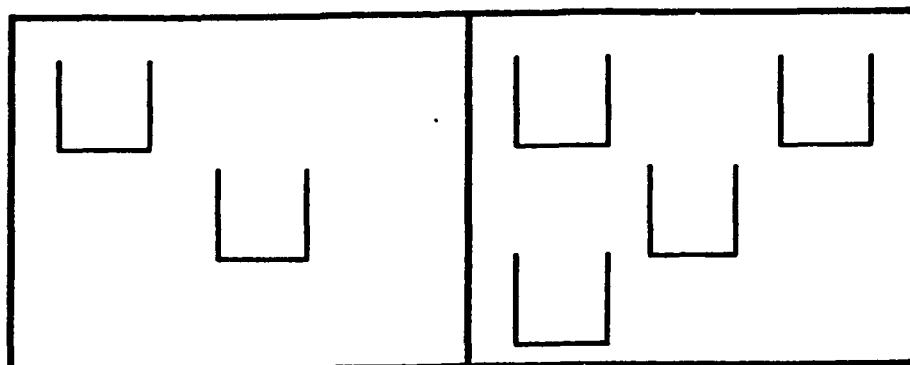
2



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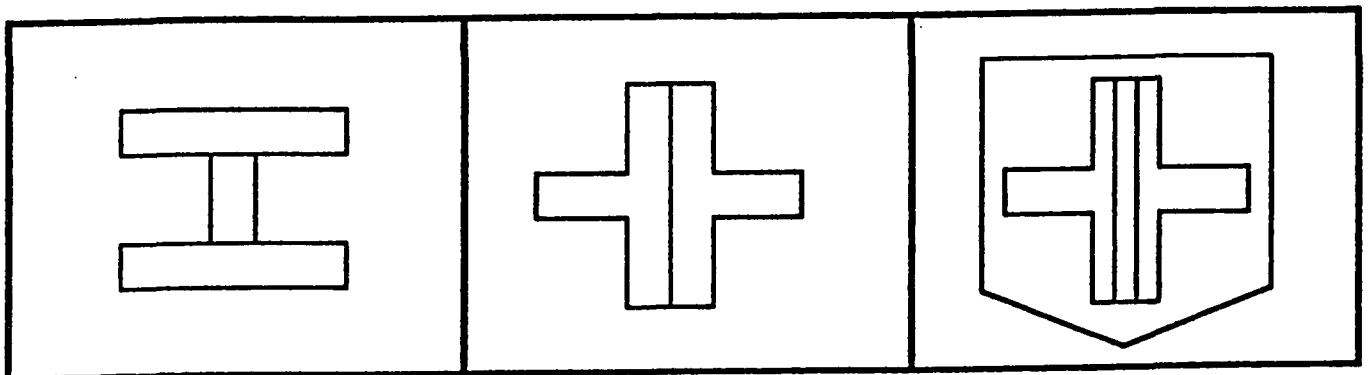
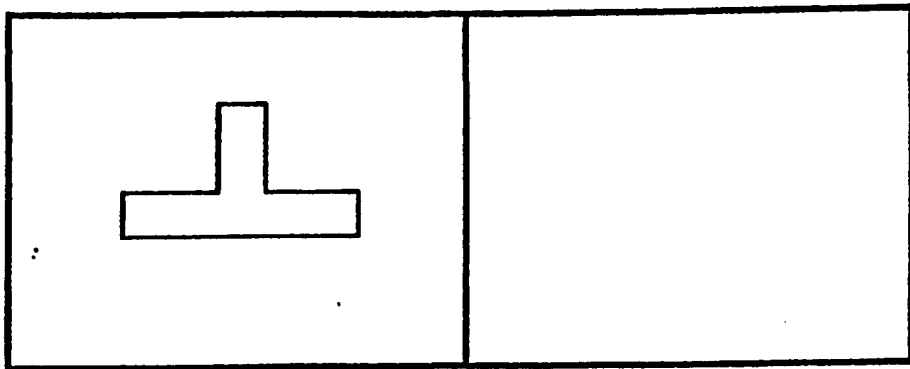
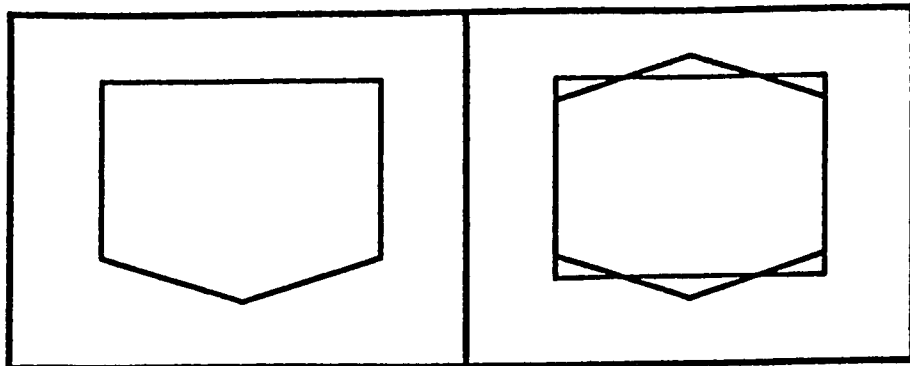
Appendix H
Figure Analogies Missed 50% of the Time

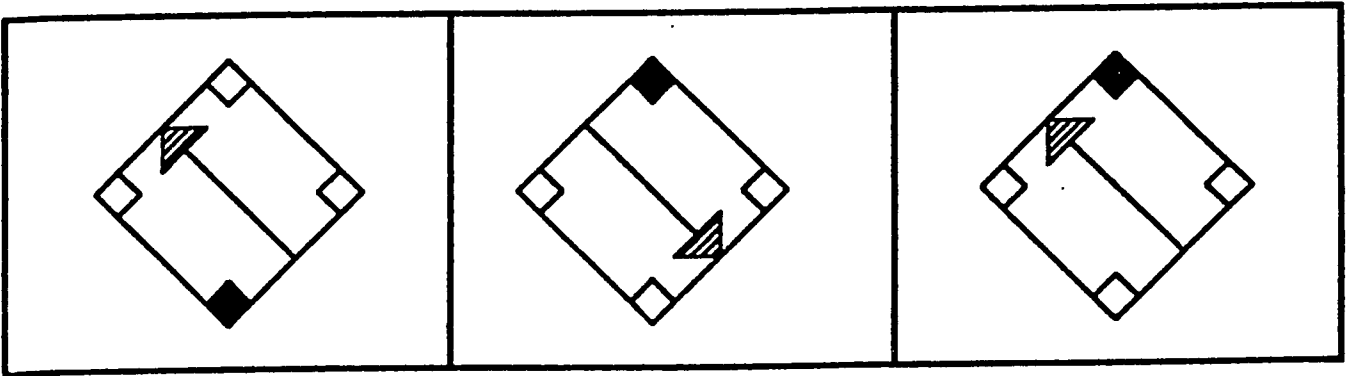
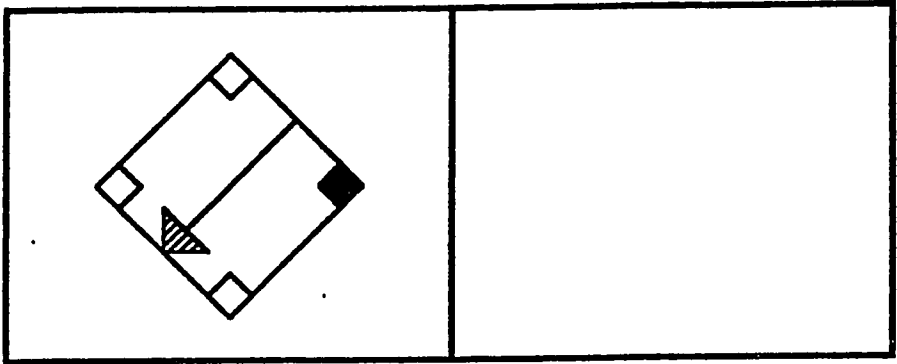
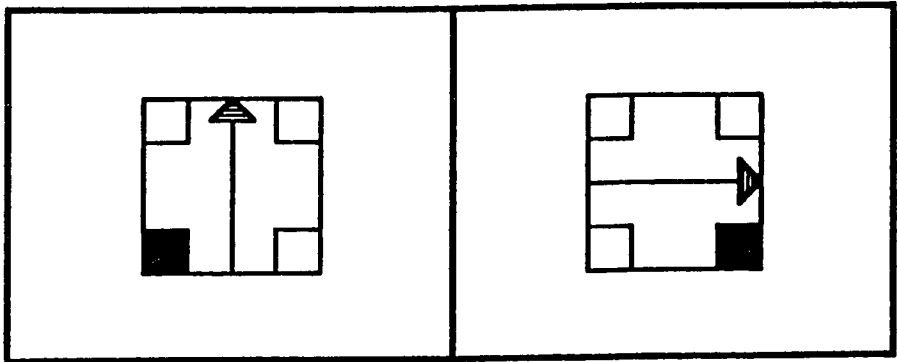


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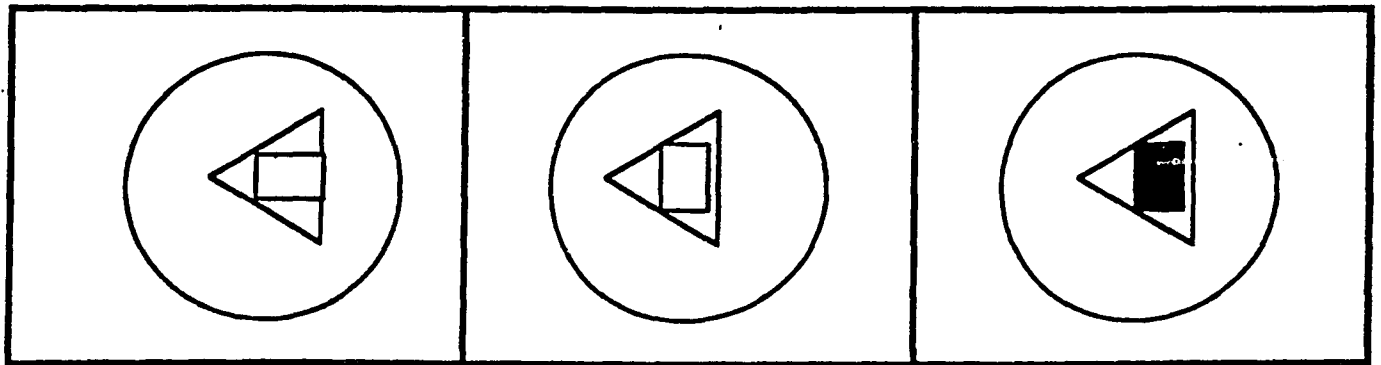
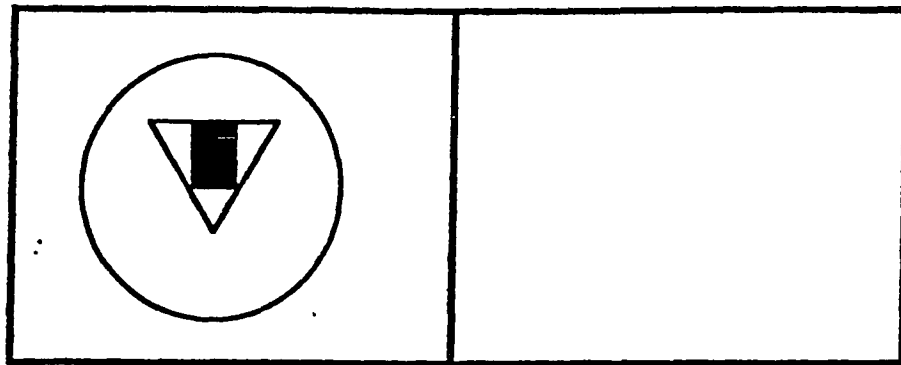
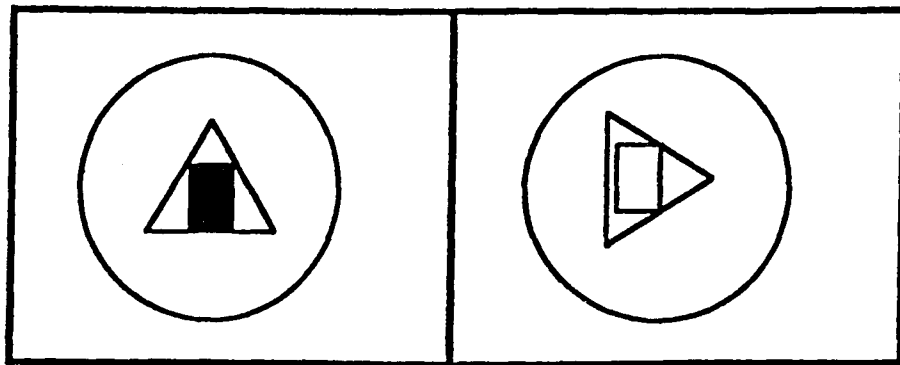
**1****2****3**

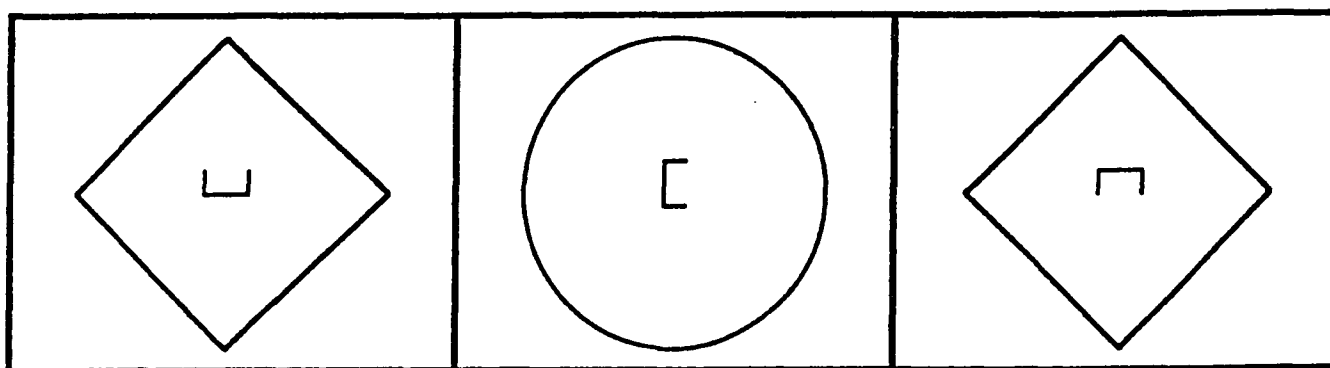
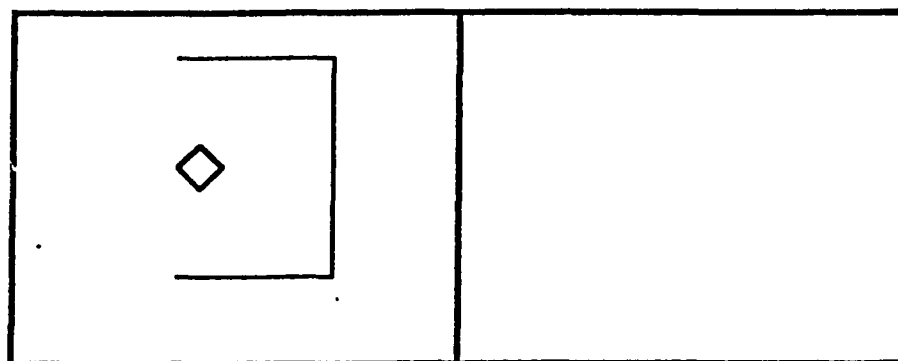
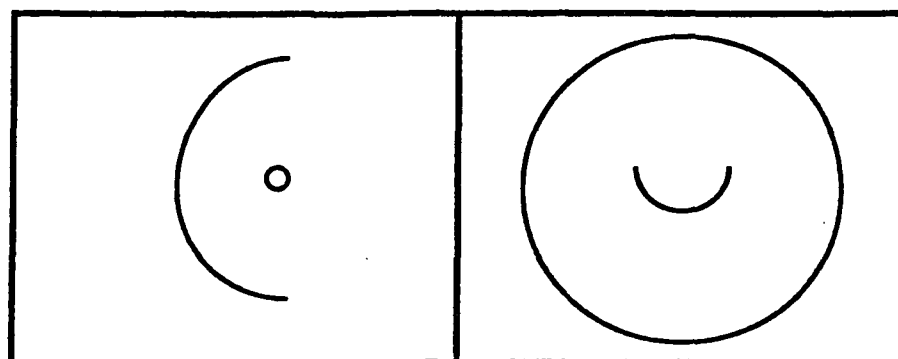


1

2

3

**1****2****3**

**1****2****3**

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