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An investigation of the inference and mapping components of
the componential theory of analogical reasoning

Sheard, Catherine, Ed.D.
The Louisiana State University and Agricultural and Mechanical Col., 1987
AN INVESTIGATION OF THE INference AND MAPPING COMPONENTS OF THE COMPONENTIAL THEORY OF ANALOGICAL REASONING

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree Doctor of Education in Curriculum and Instruction (Reading)

by

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May 1987
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A personal and special thanks to my husband, Tom. Without your patience, understanding and sacrifice this work would not have been possible. You have always believed I could achieve my goals and have given me enough love and encouragement to do so.
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ABSTRACT

Sternberg's componential theory of analogical reasoning (1977) provides a series of steps that may be followed in order to solve analogies. According to Sternberg, when given a simple analogy [in the form A : B :: C: (D₁, D₂, D₃)] the reasoner: (a) encodes the terms of the analogy, (b) infers the relation between A and B, (c) maps the relation between A and C, (d) applies a relation analogous to the inferred one from C to each answer option, choosing the closer option, and (e) responds. The purpose of this research was to further investigate the inference and mapping processes of the componential theory of analogical reasoning.

Subjects were 41 eighth graders of average and above average ability and 41 adults from two undergraduate secondary reading courses. Each subject was required to solve eight target analogies and, in a separate two-part task, to identify the relation(s) within 16 corresponding word pairs. In order to counterbalance the two tasks, subjects were randomly assigned to the analogies first or relations first condition within intact classrooms. In the analogy task half the analogies to be solved were presented in recognition format and half in production format. In the relation task each item represented the
word pair corresponding to the inference or mapping relation in the total analogy. Subjects were required to generate a list of possible relations within each word pair. Data were analyzed using a 2x2x3 mixed AVOVA (group x mode of response x relations known).

A statistically significant main effect for the number of relations known when an analogy was correctly solved was found, $p < .0001$. A statistically significant interaction between group and number of relations known when an analogy was correctly solved was also found, $p < .0001$. There was no statistically significant difference in the probability of accurately solving an analogy whether both the inference and mapping relations or either of them were known.

The data obtained here supports the contention that the reasoner is not required to both infer A-B and map A-C before correctly solving an analogy. Further, no single relation is more valuable than another for accurate analogy solution.
Analogical reasoning is used in many diverse parts of our daily lives, from helping us decide where to fish [here because this spot is just like the place where we caught the big one] to the courts where case law is used in reaching decisions. Analogies are used in educational settings to assist in instruction as well as in testing. Rumelhart and Ortony (1977) stated:

One can regard the entire comprehension process in schema theory as itself being a case of analogical reasoning. When we determine that a situation fits a certain schema we are in a sense determining that the current situation is analogous to those situations from which the schema was originally derived. Moreover, when we make inferences about unobserved aspects of the situations we are, in effect, assuming their existence by analogy from the situations from which the schemata were derived. (p. 120)

In spite of the pervasive influence of analogies there appears to be limited theoretical research into the processes involved in the task of analogical reasoning.
Review of Related Literature

For a definition of terms related to this study, see Appendix A. For a complete review of literature, see Appendix B.

Sternberg (1977b) has reviewed most of the theoretical work (excluding the philosophical) done on analogical reasoning. It appears from this review that the theories of analogical reasoning may be grouped into the following two primary divisions: (a) differential theories of analogical reasoning, such as those proposed by Spearman (1927) and Thurstone (1938), which are based on individual differences in subjects' performance on analogical reasoning tests; and (b) information-processing theories of analogical reasoning, such as those proposed by Spearman (1923) and Rumelhart and Abrahamson (1973), which are based on processes involved in analogical reasoning. Although agreeing that each type of theory offered some insight into analogical reasoning, Sternberg felt a composite of the two might best explain the phenomenon. Thus, he proposed the componential theory of analogical reasoning (Sternberg, 1977b) based on an identification of the component reasoning processes that compose the total analogical reasoning task.
Sternberg and Ketron (1982) described five basic component processes of the componential theory of analogical reasoning as follows:

These are **encoding**, by which the subject perceives an analogy term and stores in working memory (a) possibly relevant attributes of the analogy term, and (b) a value corresponding to each stored attribute; **inference**, by which the subject discovers the relation between the A and B terms of the analogy and stores the relation between them in working memory; **mapping**, by which the subject links the domain (first half) of the analogy to the range (second half) of the analogy by discovering the relation between the A and C terms of the analogy; **application**, by which the subject applies from C to each answer option a relation in the range of the analogy that is analogous to the relation inferred in the domain; and **response**, by which the subject communicates a solution. (p. 403)

The following is an example of a simple analogy [in the form A : B :: C: (D₁, D₂, D₃)] to illustrate the basic processes of the componential model of analogical reasoning:

\[
\text{HAND} : \text{FINGER} :: \text{FOOT} : \underline{\text{_______}}
\]

a) TOE  b) SHOE  c) GLOVE
According to Sternberg, the reasoner: (a) encodes the terms of the analogy, (b) infers the relation between HAND and FINGER (a finger is a digit on a hand), (c) maps the relation between HAND and FOOT (both are human appendages), (d) applies a relation analogous to the inferred one from FOOT to each answer option, choosing the closer option (a toe is a digit on a foot; neither a shoe nor a glove are digits on a foot), and (e) responds.

This study is particularly concerned with investigating the extent to which there is empirical support for the inference and mapping components of Sternberg's componential theory of analogical reasoning (1977b). Although Sternberg and colleagues have investigated further the basis for the componential theory (Sternberg, 1977a; Sternberg & Ketron, 1982; Sternberg & Nigro, 1980; Sternberg & Rifkin, 1979) and have used it as a basis for developing a theory of higher reasoning (Sternberg, 1984; Sternberg & Downing, 1982), the basic theory does not appear to have changed since Sternberg presented it in 1977. If the processes presented in the theory can be validated, then they may be used as a firm foundation from which techniques for direct instruction may be developed for use in the classroom.

Of the limited research that has been conducted on various forms of analogy (e.g., geometric, animal name),
the focus of this proposed research will be on verbal analogies as exemplified above. Relatively few studies using verbal analogies seem to have been designed to provide information that would assist in the validation of the processes of Sternberg's theory. For instance, Sternberg's (1977a, 1977b) data, detailed to support his theory, consisted of solution time and error rate data collected from investigations using university students. He used pictorial, verbal, geometric, and animal name analogies. Sternberg and Nigro (1980) examined the complete theory, using response time data and error rates to investigate developmental differences in analogical reasoning with students from grades three, six, nine, and college. All subjects received the same 180 verbal analogies. Looking at previously described components, they found that the response-time data at all levels and error data, except at the college level, were accounted for by the componential theory of analogical reasoning.

In another study starting with Sternberg's general theory of analogy solution (Sternberg, 1977b), Goldman, Pellegrino, Parseghian, and Sallis (1982) focused on the inference, application, and response components; mapping was not discussed. Their subjects, eight- and 10-year-old students, were given analogy stems from which they generated the fourth term or selected the fourth term from five provided alternatives. Response time data
were not collected. They found that individual performance differences on forced-choice analogies could be predicted approximately equally well by application, response recognition, and distractor interference measures, slightly less well by inference measures, and not at all by age.

In a study that did not support Sternberg's theory, Grudin (1980) proposed that the relational use of the first and third terms of an analogy (A and C), instead of the first and second terms (A and B), could be used effectively by some people in solving verbal analogies. Although Sternberg (1977) stated "the essence of analogy is in the higher-order relation, \( y \), that maps the domain into the range of the analogy" (p.134), Grudin felt the A-C relation was not always necessary in resolving an analogy and, thus, argued against the necessity of Sternberg's mapping process. With college students, Grudin used verbal analogies (forced choice, three alternatives). The data collected, using response time, post-task comments, and one think-aloud, showed that people can and do vary their strategies for solving verbal analogies. Based on his findings, Grudin suggested that only one relation, either the A-B or the A-C relation, has to be determined to solve the analogy.

Two studies by Sternberg and colleagues (Sternberg & Ketron, 1982, Sternberg & Rifkin, 1979), which did not
use verbal analogies, do refer briefly to the mapping process. In the former study, a training study using figural analogies, "no mapping instruction was given because subjects' introspective comments in previous research have shown that subjects are not conscious of performing the mapping process" (p.405). In the latter study it was found that second graders did not map the higher-order relation between the two halves of the pictorial analogies whereas fourth and sixth graders and adults did.

Sternberg and Downing (1982) and Sternberg (1984) studied the development of higher-order reasoning or analogies between analogies. Here Sternberg's componential theory of analogical reasoning was used as a basis to provide a broader theory to account for more complex reasoning. Thus, despite some evidence against it, Sternberg has retained the basic theory he proposed in 1977.

Need for the Study

Sternberg's theory of analogical reasoning (1977b) provides a series of steps that may be followed in order to solve analogies. The studies that provide support for this theory involve response times or error data. In particular, research on the inferring and mapping components of Sternberg's theory is equivocal. There
appears, then, to be a dearth of information concerning what is really happening while an individual is solving verbal analogies.

Therefore, it seems feasible to sample information that may be available to the individual at key points in the process of analogy solution in an attempt to provide some evidence that would assist in the validation of the inference and mapping processes of the componential theory of analogical reasoning.

The purpose of this study is to examine processes of inference and mapping as used by subjects to solve verbal analogies of the form: \( A : B :: C : (D) \), where the response \((D)\) was recognized or produced. The following questions will serve to guide this study:

(1) Are identification of: (a) the inference and mapping relations, or (b) the inference or mapping relations a precondition for the accurate solution of verbal analogies in recognition or production formats for eighth-graders and/or adults?

(2) If it is determined that the identification of only one relation is a necessary precondition for the accurate solution of verbal analogies: (a) Is the identification of the inference or mapping relation significantly more valuable? (b) Can a prediction be made about which relation will be more valuable based upon examination of the terms of the analogy?
CHAPTER TWO

METHOD

Subjects

One group of subjects was 42 eighth graders drawn from a school in a moderately-sized southern city. They were students who were considered to be average or above-average in achievement as determined by the Stanford Achievement Test administered by their school system in October 1986. Using national norms, the reading comprehension group percentile rank and stanine corresponding to the mean scaled score were 97 and 9, respectively, while the vocabulary group percentile rank and stanine were 98 and 9. There were 23 males and 19 females of which 7 were Black and 34 White. One White female subject was later dropped from the study because she moved before all tasks were completed. Thus, 41 subjects comprised the final sample of eighth graders.

The second group of subjects was 45 adults drawn from students enrolled in two undergraduate secondary reading methods courses at a large southern university. There were 21 males and 24 females of which 3 were Black and 42 White. Four of these adults (two White males and two White females) were dropped because they did not complete all tasks. Thus, 41 subjects comprised the final sample of adults.
University undergraduates were chosen as subjects because they were similar to those subjects used most frequently in previous research. Eighth graders were chosen because they are frequently exposed to analogies as they read and learn from text and because they possessed lesser amounts of prior knowledge than undergraduates.

Materials

Pilot testing was conducted in order to develop the materials used in the study. For a complete description of the pilot study see Appendix C.

The instruments were developed from an analogy set composed of verbal analogies used by Sternberg (1977a). Doctoral students in education classified the completed analogies into groups according to the relations used to build them. Although there are many different categories of analogical relations, four defined by Whitely & Dawis (1973) were used: (a) functional, (b) class naming, (c) similarity, and (d) opposites. Those analogies which could not be classified into one of the four groups were labelled as unclassifiable. See Appendix D for a definition of these categories and the materials used to categorize the analogies. Four analogies classified as class naming and four classified as functional were chosen to be the target analogies for the study because they were the only two categories containing four or more
analogies from the target pool. More than one category of target analogies were desired to make the results of this study more generalizable.

Doctoral students in education also identified the pair of words in the analogy stem that showed the relation used for classifying the analogy. This pair was labelled as the A-B pair and was described as having the stronger relation; the A term and the remaining term in the stem were labelled as the A-C pair and were described as having the weaker relation. For example, if given the analogy: surgeon : scalpel :: sculptor : chisel, the A-B pair, that is, the pair showing the stronger relation, would be surgeon-scalpel and the A-C pair, that is, the pair showing the weaker relation, would be surgeon-sculptor. Appendix D also includes the materials used for relations identification.

The first instruments developed for data collection were the analogy solution tasks (See Appendix E). Each contained the eight target analogies and eight distractor analogies. The analogies were presented in two formats: (a) recognition and (b) production. The analogies in the recognition format used the stem (A : B :: C : _ ) on one line and the alternative choices (D₁, D₂, D₃, D₄, D₅) listed vertically below. Subjects circled the alternative which best completed the analogy. The analogies in production format appeared with the stem
(A : B :: C : _) on one line and a space for the response on the right. Two forms of each analogy were prepared by reversing the B-C terms of each target analogy. This was done in order to focus attention on the inference and mapping processes rather than the word pairs involved in the process. For instance, one form of the target analogy appeared as such: surgeon : scalpel :: sculptor : chisel. With the B-C terms reversed the analogy appeared as: surgeon : sculptor :: scalpels : chisel. In all four forms of the analogy tasks (designated as I, II, III, and IV), each target analogy was presented in each combination of sequence and response format; however, in any single form of the analogy task, each analogy appeared only once.

The second set of instruments used in data collection was the relations tasks (See Appendix F). Each complete task was composed of a list of 16, randomly ordered, word pairs derived from the target analogies. Each item represented an A-B or A-C word pair. Subjects were required to generate a list of possible relations within the word pairs given. A column of eight blanks for the responses was drawn below each pair of words. Two forms of the relations task were prepared (designated as A and B), each of which was divided into two parts.
Procedure

Each subject was required to solve eight target analogies and, in a separate two-part task, to identify the relation(s) within 16 corresponding word pairs. The subjects were allowed 20 minutes to complete the task involved in each session. Data collection occurred in three separate sessions spaced at intervals of 10 or more days. In order to counterbalance the two tasks, subjects were randomly assigned to the analogies first or relations first condition within intact classrooms. Within each class subjects were randomly assigned to receive analogy task form I, II, III, or IV and relations task form A or B. The researcher administered all forms of the analogy and relations tasks to the eighth-grade students and one class of undergraduates. Two other researchers, trained in the procedure of this study, administered all forms of the analogy and relations tasks to the second class of undergraduates.

Scoring. Directions for scoring and scoring keys were prepared for each task (See Appendix G). The analogy tasks and relations tasks were scored by the investigator and four doctoral students in education. Following a training session, raters each scored different forms of the analogy and relations tasks and each scored copies of a common set of randomly selected analogy and relations tasks. All scoring was done
independently, using a prepared scoring key and set of directions. Scores from the common set of tasks were used to determine inter-rater agreement. Scoring on the analogy tasks showed a .99 inter-rater agreement and on the relations task showed a .95 inter-rater agreement.

**Analysis.** Data were analyzed using a 2 (age) x 2 (mode of response) x 3 (number of relations known) mixed analysis of variance. The between subjects factor was group, the within subjects factors were mode of response and number of relations known, and the dependent measure was the accuracy of the analogy solution.

Initial inspection of the data indicated both non-homogeneity of cell variances and a large number of scores of zero (maximum score was four). Thus, transformed scores were developed to be used for the repeated measures analysis of variance. These scores were calculated using the formula: \[ X' = \sqrt{X + 0.5} \] (transformed score = square root of (raw score + .5)). The Scheffé post-hoc test for multiple comparisons was used to compare group means. Given knowledge of specified relations, the probability of correctly solving analogies was determined; significance was established by using a Z-test for the equality of proportions.
Means and standard deviations for the number of accurately solved analogies for the eighth graders and adults by the mode of response and the number of relations known are presented in Table 1.

Insert Table 1 about here

The mixed analysis of variance on the transformed scores identified a statistically significant main effect for the number of relations known when an analogy was correctly solved, $F(2, 400) = 237.70, p < .0001$. The Scheffé multiple comparison test indicated that the number of analogies correctly solved when two relations were known was significantly higher than when one relation was known, which was itself also statistically significantly higher than when no relations were known (all $p$s < .01). No other main effects were statistically significant.

A statistically significant interaction between group (eighth graders, adults) and number of relations known when an analogy was correctly solved was also identified.
### Table 1
Means and standard deviations of the number of correct analogies by group, mode of response, and number of relations identified

<table>
<thead>
<tr>
<th>Number of relations identified</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td><strong>Group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8th (n = 41)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition</td>
<td>2.05</td>
<td>1.25</td>
<td>1.12</td>
</tr>
<tr>
<td>Production</td>
<td>2.07</td>
<td>1.25</td>
<td>0.85</td>
</tr>
<tr>
<td>Total</td>
<td>4.12</td>
<td>2.19</td>
<td>1.97</td>
</tr>
<tr>
<td>Adult (n = 41)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition</td>
<td>2.90</td>
<td>1.11</td>
<td>0.63</td>
</tr>
<tr>
<td>Production</td>
<td>2.76</td>
<td>1.20</td>
<td>0.90</td>
</tr>
<tr>
<td>Total</td>
<td>5.66</td>
<td>2.01</td>
<td>1.54</td>
</tr>
<tr>
<td>All</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recognition</td>
<td>2.48</td>
<td>1.26</td>
<td>0.88</td>
</tr>
<tr>
<td>Production</td>
<td>2.41</td>
<td>1.27</td>
<td>0.88</td>
</tr>
<tr>
<td>Total</td>
<td>4.89</td>
<td>2.23</td>
<td>1.76</td>
</tr>
</tbody>
</table>

**Note.** Total number of analogies possible summed across relations identified = 8
by the mixed analysis of variance, $F(2, 400) = 11.01$, $p < .0001$. The Scheffé multiple comparison test indicated that the difference between the number of analogies correctly solved by adults and by eighth graders when two relations were known was statistically significantly different from the difference between the number of analogies correctly solved by adults and by eighth graders when one relation was known. No other interactions were statistically significant.

The probability of obtaining a correct or incorrect analogy solution was determined for specified relations knowledge. Table 2 presents the frequency counts and the probabilities of stated analogy solution accuracy by group and number of relations known. The Z-test for equality of proportions indicated that at $p < .05$ there were statistically significant differences: (a) for all subjects between the probability of correctly solving the analogy when no relations were known and when one relation was known; (b) for eighth-grade subjects between the probability of correctly solving the analogy when no relations were known and when one relation was known; and (c) between eighth-grade and adult subjects for the probability of correctly solving the analogy when one relation was known.

____________________

Insert Table 2 about here

____________________
Table 2
Frequency counts and probabilities of stated analogy solution accuracy by group and number of relations known

<table>
<thead>
<tr>
<th>Number of relations identified</th>
<th>Group</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8th</td>
<td>169</td>
<td>81</td>
<td>17</td>
</tr>
<tr>
<td>Analogies correct</td>
<td></td>
<td>[.84]</td>
<td>[.83]</td>
<td>[.61]</td>
</tr>
<tr>
<td>Analogies incorrect</td>
<td></td>
<td>33</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>202</td>
<td>98</td>
<td>28</td>
</tr>
<tr>
<td>Adult</td>
<td></td>
<td>232</td>
<td>63</td>
<td>4</td>
</tr>
<tr>
<td>Analogies correct</td>
<td></td>
<td>[.90]</td>
<td>[.94]</td>
<td>[1.00]</td>
</tr>
<tr>
<td>Analogies incorrect</td>
<td></td>
<td>25</td>
<td>04</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>257</td>
<td>67</td>
<td>4</td>
</tr>
<tr>
<td>All</td>
<td></td>
<td>401</td>
<td>144</td>
<td>21</td>
</tr>
<tr>
<td>Analogies correct</td>
<td></td>
<td>[.87]</td>
<td>[.87]</td>
<td>[.66]</td>
</tr>
<tr>
<td>Analogies incorrect</td>
<td></td>
<td>58</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>459</td>
<td>165</td>
<td>32</td>
</tr>
</tbody>
</table>
Further analysis was completed on characteristics of the single relation known when it was accompanied by a correct analogy solution. Table 3 presents the frequency counts and the probabilities of stated analogy solution accuracy when only one relation was known by group and described relation. There were no statistically significant differences found in the probability of having the correct analogy solution when knowing: (a) only the inference or mapping relation, or (b) only the stronger or weaker relation.

Insert Table 3 about here

When the frequency count was examined, it was seen that when only one relation was identified the inference relation and mapping relation appeared with approximately the same frequency. However, at the same time, the data showed that when only one relation was identified the stronger relation and weaker relation appeared in the ratio of approximately three to two with eighth graders and four to one with adults.
Table 3

**Frequency counts and the probabilities of stated analogy solution accuracy when only one relation is known by group and described relation**

<table>
<thead>
<tr>
<th>Relation identified</th>
<th>Inference</th>
<th>Mapping</th>
<th>Strong</th>
<th>Weak</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>8th</strong></td>
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CHAPTER 4
DISCUSSION

The purpose of the present study was to examine the processes of inference and mapping as used by subjects to solve verbal analogies. In taking into account the generalizability of the results of this study, the following limitations should be considered. First, the eighth-grade subjects were students of average and above average ability. The findings may have varied given students of different age and ability ranges. Second, the analogies used were chosen from those used in a previous study (Sternberg, 1977a, 1977b). With these analogies there appeared to be a ceiling effect; that is, most subjects accurately solved most analogies. It is possible that other analogies may have provided different results. Third, the relations task and the analogy task were separated so as to minimize the possible influence of one on the other. It is possible that different relations might be identified when words appear within the context of the full analogy rather than as isolated word pairs. Finally, in order to assess subjects' knowledge of specific relations, a free recall, written format was utilized. Although this format allows for ecological validity, it is only one of many that may have
been used. If subjects who participated in this study were evaluated using alternative testing formats, results may have varied.

Given the limitations of this study, the following conclusions can be drawn. First, the probability of accurately solving an analogy was no different whether both the inference and mapping relations or either of the inference or mapping relations was known. When Sternberg (1977a) related his experimental data to the component information processes, he contended that both inference and mapping were shown to be involved in all the analogy solution tasks investigated. Later, he reiterated (Sternberg, 1985) that inference and mapping are two of the processes required for the solution of analogies similar to those in this study. On the other hand, Grudin (1980) presented a variant to this theory wherein only one of either the inference or mapping relations was required for analogy solution. In a note appended to Grudin's study, Sternberg attempted to account for these findings by contending that when subjects try inferring $A-B$ and mapping $A-C$ and fail, they then may proceed to infer $A-C$ and map $A-B$ and, thus, not eliminate either process. Though Sternberg appeared to have tempered somewhat his interpretation of his theory, as stated previously, he reiterated the necessity of both the inference and mapping processes in a later
publication (Sternberg, 1985). The data in this study does not seem to support Sternberg's theory; it suggests that both the inference and mapping relations are not required for accurate analogy solution. The data does provide support to Grudin's proposal that only one of these two relations is necessary.

Second, subjects could solve these analogies equally as well whether they were presented in recognition or production format. In other studies, investigating aspects of the componential theory of analogical reasoning, analogies are generally presented in recognition format only (e.g., Grudin, 1980; Sternberg, 1977a; Sternberg & Nigro, 1980). Although Alderton, Goldman, and Pellegrino (1985) and Goldman, Pellegrino, Parseghian, and Sallis (1982) reported using both formats in the course of their investigations, there appears to be no published comparison of the rate of accuracy of analogy solution between the two formats. That there is no difference between recognition and production does seem contradictory to general educational thought which states that the production of an answer is more difficult/demanding than the recognition of an answer. However, this may have occurred due to the depth of knowledge subjects had regarding the vocabulary, concepts, and relations used in these analogies. The data from this study suggests that the use of the
processes of inference and mapping to solve verbal analogies may be generalized to analogies presented either the recognition or the production format.

Third, there was no difference between eighth graders and adults with respect to the proportion of analogies accurately solved when two or more relations were known. At the same time, the group x relation interaction seems to indicate that adults knew more relations than did eighth-grade subjects. Eighth graders knew only one relation for more analogies than did adults whereas adults knew two relations for more analogies than did eighth graders. This seems to confirm the intuitive notion that adults possess more prior knowledge than eighth-grade subjects.

Fourth, for analogies correctly solved when only one relation was known, neither the inference nor the mapping relation was more valuable. A relation described as more valuable increased the probability of accurately solving the analogy when only that relation was known over the probability when only the other relation was known. By changing the order of the terms within the analogy for half the analogies, any bias that could have been introduced by the presence of specific word pairs in specific positions was avoided. There were only a few more analogies accurately solved with only the inference relation known than with only the mapping relation
known. Grudin (1980) theorized that subjects would first attempt to infer the relation between the first two terms of the analogy and, if unsuccessful, would attempt to discover the relation between the first and third terms of the analogy. He suggested that only one of the two relations was needed. On the other hand, Alderton, Goldman, and Pellegrino (1985) used a procedure that either prevented the possible use of the mapping relation alone (when the response format was production) or confounded the use of mapping with the effect of response alternatives (when the response format was recognition). Alderton et al. did not identify mapping as a possible process associated with analogy solution. The results observed in the present study not only support the position that only one of the inference and mapping relations is needed but also that neither is dominant over the other.

Finally, although both a stronger and a weaker relation were identified for each analogy, neither relation appeared significantly more valuable when solving the given analogies. However, the stronger and weaker relations did appear in the ratio of approximately two to one. This is consistent with the position that the strength of the relation is within the word pair and not within their relative positions.

The concept of a stronger or a weaker relation within the analogy is not entirely new but is approached here in
a slightly different manner. Sternberg (1977b) had subjects (not involved in solving the analogies) rate the "associative relatedness" of randomly presented pairs of words. The ratings data was used in assigning items to forms. Grudin (1980) developed a concept of "usefulness" of the relation linking two terms in analogy solution. By definition the shorter solution time followed the occurrence of the most useful relation when the first two terms were studied before the complete analogy stem was presented. This information was used in arranging test items into analogy sets. It would seem that all three measures should be correlated although they are not the same. Sternberg's associative relatedness was determined independently from the analogy, while Grudin's usefulness and strength (this study) were measured within the analogy. Unlike either of the earlier studies, this study relates knowledge of a specific relation with accuracy of analogy solution. If one only looks at which single relation was most frequently known when the analogy was correctly solved it would appear, and logically so, that the stronger relation is best. If, however, the value of the known relation is determined, then it becomes apparent that it does not matter which relation that is, for the probability that the analogy will be accurately solved does not differ. Obviously, the weaker relation is not less valuable for everyone.
In this study it appears that both eighth-grade and adult subjects are able to solve analogies as effectively when only one relation is known as when two relations are known. Although this study was not instructional in nature and was not designed to provide definitive steps for teaching others how to solve analogies, the following implication for instruction is suggested. Some modification of the componential theory of analogical reasoning might be considered for use in teaching students to solve analogies, either to augment or in lieu of what is common classroom practice. Further, this teaching model should probably include a segment that demonstrates how to proceed if the inference relation is unknown as well as how to proceed if the mapping relation is unknown.

Future research might focus on the involvement of students with a wider range of achievement and at different age levels to add support to the findings of this study. The use of a different set of analogies, perhaps those that use a less dominant relation between a pair of terms, would also add to the findings of this study. Finally, of interest might be a study which explores the effects of using Sternberg's theory as a teaching model with the adaptation mentioned above in an actual classroom situation.
In summary, it appears that the identification of either the inference or mapping relation is a precondition for the accurate solution of analogies in recognition or production format for both eighth-grade and adult subjects. Additionally, neither the inference nor the mapping relation and neither the weaker nor the stronger relation appear significantly more valuable for the accurate solution of analogies.
REFERENCES


APPENDIX A

DEFINITION OF TERMS
Definition of Terms

For the purpose of this study, the following terms are defined according to Sternberg (1977):

analogy - a hierarchy of relations formed when there is a higher-order relation of equivalence or near-equivalence between two lower-order relations (A is to B and C is to D; A:B :: C:D).

application - process by which a rule, analogous to that inferred in the domain, is formed and then is applied to C producing an image of the correct answer which may be used to judge the alternatives given.

compomentional theory of analogical reasoning - a general theory of analogical reasoning wherein the mental operations involved in analogical reasoning and the way in which they combine are specified.

domain - refers to the A and B terms of the analogy.

encoding - process during which a stimulus is translated into an internal representation.
**inference** - process by which a rule is discovered which relates the A term to the B term of the analogy.

**mapping** - process by which a rule is discovered which relates the A term (first term of the domain) to the C term (first term of the range).

**range** - refers to the C and D terms of the analogy.
Review of Literature

This review of the literature first discusses examples of the types of theories of analogical reasoning that have been proposed. Following this is an examination of the development of the componential theory of analogical reasoning. Then, a review of research using simple analogies to examine the processes involved in analogical reasoning is presented. Although the proposed research is directly concerned only with processes involved in solving simple analogies, research investigating the processes and functions of story type analogies is included to provide a more balanced picture of the current research knowledge about analogies. For the same reason, the review concludes with a section focusing on the use of analogies in the instructional setting.

Theories of Analogical Reasoning

Sternberg (1977b) reviewed most of the theoretical work (excluding the philosophical) done on analogical reasoning. From this review it appears that many theories of analogical reasoning are closely related to theories of intelligence. This is understandable when one realizes that they frequently developed from, or were
a part of, research on intelligence. The theories of analogical reasoning presented may be grouped into the following two primary divisions: (a) differential theories of analogical reasoning, and (b) information-processing theories of analogical reasoning.

Differential theories of analogical reasoning were actually proposed as theories of intelligence; therefore, they are generally rather incomplete. Individual differences in subjects' performance on given analogical reasoning tests provided the basis for their development. Two examples of differential theories of analogical reasoning are the theories proposed by Spearman (1927) and Thurstone (1938). Spearman associated analogical reasoning with the g, or general factor, theorizing that performance on an analogy test is almost a pure measure of g. He used data showing high correlations between the g-factor and analogy tests to add to the validation of his two-factor theory of intelligence. The second factor was a set of factors, each of which was relevant to a specific task; thus, each intellectual activity involved the common factor (g-factor) and a specific factor. Spearman's theory is best suited to analogies in which vocabulary plays an unimportant role, that is, where the potential verbal factor plays a minor role in interpretation.
Thurstone (1938), on the other hand, used verbal and pattern analogies to help validate his multiple factor theory of intelligence. The seven proposed factors were: (a) inductive reasoning, (b) memory, (c) number, (d) perceptual speed, (e) space, (f) verbal comprehension, and (g) verbal fluency. Perhaps because content was not clearly separated from process, the pattern of factor loading presented was confusing (e.g., on the factor for inductive reasoning the loading for pattern analogies was .39 but, for verbal analogies, it was trivial [Sternberg, 1977b].) Neither the differential theories of analogical reasoning of Spearman nor of Thurstone clearly described the processes involved in analogical reasoning.

Information processing theories of analogical reasoning focus more on the processes involved in the reasoning. Two examples of information processing theories of analogical reasoning are those proposed by Spearman (1923) and Rumelhart and Abrahamson (1973). Spearman (1923) offered a very general theory. He based it on three principles of cognition which were required for and applicable to analogies of all types: (a) apprehension of experience (i.e., stimulus is perceived and a schema activated), (b) eduction of relations (i.e., a relation between the first two terms of the analogy is found), and (c) eduction of correlates (i.e., the relation found in (b) is applied to the third term in
order to determine the fourth term of the analogy). Although these principles were identified, the processes used in solving analogies and how they are executed were not well specified. This theory also lacked supporting experimental evidence.

The theory of Rumelhart and Abrahamson (1973) detailed the internal representation of information. Specifically, an analogy is seen as a parallelogram in semantic space with the four terms placed at the corners of the parallelogram; analogical reasoning is seen as a set of operations (not detailed by Rumelhart and Abrahamson) in that semantic space. Although experiments provided supporting evidence for this theory of analogical reasoning, the processes used in solving analogies and how they were executed were, again, not well specified.

While agreeing that each type of theory offered some insight into analogical reasoning, Sternberg felt a composite of the two types might best explain the phenomenon. He was aware that the theories showed limitations in four general areas including the: (a) absence of empirical support, (b) incompleteness of the theories, (c) non-generality of the theories, and (d) the inability of the theories to account for individual differences in information processing. Subsequently, he proposed the componential theory of analogical reasoning
(Sternberg, 1977b) based on an identification of the component reasoning processes that compose the total analogical reasoning task. This theory cannot be classified as either a differential or an information processing theory because it has characteristics of both. Individual differences in performance (e.g., solution time and error rate) on given analogical reasoning tasks provided data in support of the theory development. The component processes identified seem to have been expanded from those specified by Spearman (1923) and combined with the concept of internal representation of analogy as specified by Rumelhart and Abrahamson (1973).

Componential Theory of Analogical Reasoning

Sternberg and Ketron (1982) described the basic component processes of the componential theory of analogical reasoning as follows:

These are encoding, by which the subject perceives an analogy term and stores in working memory (a) possibly relevant attributes of the analogy term, and (b) a value corresponding to each stored attribute; inference, by which the subject discovers the relation between the A and B terms of the analogy and stores the relation between them in working memory; mapping, by which the subject links the domain (first
half) of the analogy to the range (second half) of the analogy by discovering the relation between the A and C terms of the analogy; application, by which the subject applies from C to each answer option a relation in the range of the analogy that is analogous to the relation inferred in the domain; and response, by which the subject communicates a solution. (p. 403)

The following is an example of a simple analogy [in the form A : B :: C: __D__ ] to illustrate the basic processes of the componential model of analogical reasoning:

DOG : PUP :: CAT : __(KITTEN)__

According to Sternberg, the reasoner: (a) encodes the terms of the analogy, (b) infers the relation between DOG and PUP (the young of a dog is a pup), (c) maps the relation between DOG and CAT (both are examples of pets that have litters), (d) applies a relation analogous to the inferred one from CAT to form an ideal answer (the young of a cat is a kitten), and (e) responds with the answer KITTEN. Although the examples provided by Sternberg and colleagues to explain the theory in the literature employed a recognition format, this researcher will use a production format to see if Sternberg's theory can also account for findings resulting from such a format.
A comparison of Sternberg’s description of the componential model of analogical reasoning as presented in 1985 with that originally presented in 1977 shows that his presentation of the theory has changed slightly, but not significantly, since it was first presented. Since its original presentation, Sternberg and colleagues have investigated further the basis for the componential theory (Sternberg, 1977a; Sternberg & Ketron, 1982; Sternberg & Nigro, 1980; Sternberg & Rifkin, 1979) and have used it as a basis for developing a theory of higher reasoning (Sternberg, 1984; Sternberg & Downing, 1982).

As introduced by Sternberg in 1977, the componential theory of analogical reasoning consisted of six information-processing components. The five required processes were: (a) encoding, (b) inference, (c) mapping, (d) application, and (e) preparation-response; the optional process was justification, by which the student justifies which answer option provided is closest to the visualized answer if none are identical to it. Later, Sternberg and Rifkin (1979) specified that the processes of analogical reasoning were: (a) encoding, (b) inference, (c) mapping, (d) application, (e) justification, and (f) response, with mapping and justification identified as optional. From this researcher’s investigation, Sternberg and Rifkin (1979) appears to be the only published manuscript wherein
mapping is named, by Sternberg, as optional rather than required.

Sternberg and Nigro (1980) listed six information-processing components (encoding, inference, mapping, application, justification, and response), none of which are described as optional. Sternberg and Nigro stated that the results of their research provided developmental support for the componential theory of analogical reasoning and made it necessary to "augment the previously proposed theory with an account of how word association can be used in the solution of analogies." (p. 37) Sternberg and Ketron (1982) also identified the same six basic component processes in analogical reasoning, noting that justification "does not apply to analogies with very well-defined attributes." (p. 403) Finally, none of the six information-processing components named by Sternberg and Downing (1982) for use in evaluating the goodness of an analogy are identified as optional; this suggests all are required.

In preparation for the presentation of a proposed theory of higher-order analogical reasoning Sternberg (1984) suggested that processing of simple analogies could best be understood in terms of seven basic components of information processing: (a) encoding, (b) inference, (c) mapping, (d) application, (e) justification, (f) response, and (g) association (i.e., a
process in which an answer is selected based on the association between the C term and the response).

Sternberg stated that although the first six components are sufficient to solve any given simple, four-term analogy, research evidence indicated that some individuals, especially younger children, used association instead of, or in addition to, the other processes. He also indicated that a comparison component would need to be added for analogies in a multiple-choice format. Finally, Sternberg (1985) summarized and presented the componential model of analogical reasoning and, in this case, theorized that seven information processing components are required: (a) encoding, (b) inference, (c) mapping, (d) application, (e) comparison, (f) justification, and (g) response.

In conclusion, throughout all statements of Sternberg's componential theory of analogical reasoning it can be seen that encoding, inference, mapping, application, and response have generally been the basic components required for analogy solution. Comparison and justification, on the other hand, seem to be additional processes used for analogies presented in true/false or multiple choice formats, while association seems to be a process that may be used in addition to or instead of other processes by some individuals for some analogies.
Following Sternberg's componential theory of analogical reasoning, if both the AB relation and the AC relation are identified and used appropriately, then the D term should be accurately chosen or produced. As will be seen in the following section, the existence and operation of the relations referred to above have been given some support by mathematical modeling using response time and error rate data. This researcher sampled information that may be available to individuals at key points in the process of analogy solution, that is, to tap into individuals schemata' to delineate whether the AB and AC relations are identified.

Research on Analogies

The literature in the area of analogical reasoning can be separated into strands composed of: (a) those investigating simple analogies in the form A:B :: C:D, and (b) those investigating analogies in the form of stories. Each of these two strands can, of course, be teased apart into more narrowly defined sections. This portion of the review of the literature examines briefly each of these identified strands so as to suggest our current understanding of analogies from a research viewpoint.

Simple analogies. Investigations involving simple analogies in the form A:B :: C:D tend to: (a) focus on
how such analogies are solved, and (b) use one or more of
the dot, verbal, geometric, animal name, schematic
picture, people piece, or numerical type analogies.
Some, but not all, of the investigations seem to have
been designed to provide information that would assist in
the validation of the processes of Sternberg’s (1977b)
componential theory of analogical reasoning.

Data obtained using verbal, geometric, and people
picture analogies (true/false) with university students
provided Sternberg (1977a, 1977b) with support for the
processes of inference, mapping, and application as
identified in his componential theory of analogical
reasoning. Solution time and error rate were used as
dependent variables. Sternberg and Nigro (1980) used
verbal analogies (forced choice, four alternatives) to
investigate the presence of a developmental pattern in
the solution of such analogies. Solution time and error
rate were again used as dependent variables; all subjects
(third-grade, sixth-grade, ninth-grade, and college
students) received the same 180 verbal analogies. The
data supported the generalizability of Sternberg’s theory
within the verbal domain; however, there seemed to be a
association process used in the solution of analogies
that decreased with age.

Other studies have supported the notion of a
developmental trend in analogical reasoning. Goldman,
Pellegrino, Parseghian, and Sallis (1982) examined individual differences in the solution of verbal analogies by third-grade and fifth-grade students; later Alderton, Goldman, and Pellegrino (1985) similarly examined undergraduate students. Subjects were required to generate an A-B relational rule (inference), generate the fourth term, and solve verbal analogies (forced choice, five alternatives). Generation of the correct fourth term was interpreted as a correct application. The results of Goldman et al. (1982) suggested that, in forced-choice analogy tasks, the presence of terms in the alternative answers that are associated with the C term may make items more difficult to solve for young children or less skilled reasoners. Goldman et al. also observed that even when explaining a correct response less skilled reasoners were just as likely to refer to no relation or to an irrelevant one as to refer to a parallel relation between the pairs of terms.

The analogical processing model described by Alderton et al. (1985) was somewhat different in that no reference was made to mapping. Their results suggested that undergraduates were less distracted by the presence of terms associated with the C term in the alternative answers than were the younger students in the Goldman et al. (1982) study, perhaps because they have a better developed understanding of the characteristics of an analogy.
Sternberg and Downing (1982) examined the development of higher-order reasoning in adolescents using higher-order verbal analogies (analogy between analogies). Eighth-grade, eleventh-grade, and college students were required to indicate how well related the pairs of analogies (forming each higher-order analogy) were to each other. Two developmental trends that had been observed earlier with regard to solving standard analogies were seen again in solving higher-order analogies: (a) a movement away from just associative relations and toward the use of the analogical relations specified by Sternberg, and (b) that mapping enters into reasoning by analogy relatively later than other operations.

That it is possible for individuals to use different strategies to solve different analogies was suggested by researchers who used verbal and geometric analogies. Grudin (1980) used verbal analogies (forced choice, three alternatives) to verify the "asymmetry" (p. 68) of some analogies and to show that people can and do vary their strategies for solving verbal analogies. Generalizing from the responses produced by undergraduate students, Grudin proposed a modification to Sternberg's theory: only one relation, either the A-B (inference) or A-C (mapping), and application are required to solve an analogy.
In a study focusing on individual differences, Bethell-Fox, Lohman, and Snow (1984) required high-school students to complete geometric analogies (forced choice, two and four alternatives). The results indicated that subjects may shift strategies between and within items; it seemed that at least two different cognitive processing strategies were being used. Bethell-Fox et al. found that higher ability subjects did not take longer to encode although they showed better recognition and recall for item attributes. The notion that such individuals activate more complex schemata is in agreement with this observation.

An alternative interpretation of the processes involved in analogical reasoning to that proposed by Sternberg suggests that if either the AB or the AC relation is identified and properly used, then D should be accurately chosen or produced. The viability of this alternative, suggested by Grudin (1980), is supported by the notion that subjects solving geometric analogies may use more than one strategy (Bethell-Fox et al., 1984). By tapping into subject's schemata to determine the AB and/or AC relations identified, the current research may provide data that will support one or other of the interpretations offered.

Research has suggested that students, who may not have understood the strategy of analogical reasoning,
have benefited from appropriate direct instruction. Bisanz, Bisanz, and LeFevre (1984) dealt with dot analogies (true/false) similar to those found on psychometric tests. Their concern was with the effect of incomplete instructions on the performance of fourth-grade, sixth-grade, eighth-grade, and university students. Bisanz et al. determined that some individual differences in analogical reasoning may be due to failure to understand problem constraints and consequent use of inadequate strategies. There was an indication that students who failed to use an analogical rule were capable of using it if that rule was made explicit; i.e., support was provided for the notion that direct explicit instruction in the strategies involved in analogical reasoning may benefit students.

Sternberg and Ketron (1982) examined the effect of instruction in specific strategies and no instruction on the solution of figural analogies (forced-choice, two alternatives) by undergraduate students. Solution time and error rate were used as dependent variables; specific instructions, content of the analogies, and item difficulty were independent variables. Mapping was not included in any instructional sequence. The results supported the premise that it is possible to train students to use a strategy to solve figural analogies. Additionally, Sternberg and Ketron concluded that
"content can play a major role in effects of training on subjects' selection and implementation of strategies in analogical reasoning and also in their apparent knowledge of the strategies they select and implement." (p. 412)

Although the present study did not include an instructional component, the literature revealed that instructional programs for the solution of simple analogies have been designed. Alexander (1984), Alexander, White, and Mangano (1983), and White and Alexander (1984) have developed an instructional sequence based upon Sternberg's (1977b) componential theory of analogical reasoning. Within the direct instruction model, elementary students learned to name and explain each of the analogical components (encoding, inferring, mapping, applying) and to solve analogies carefully sequenced from simple to complex. The authors indicated that participating students made significant gains in their analogical reasoning performance. Interestingly, with the exception of response time and error rate data, there has not been any validation of the processes involved in Sternberg's theory of analogical reasoning upon which this instructional model is based.

In an earlier study, Whitely and Dawis (1973) taught high-school students categories for analogies based on the relations used in the analogies. They determined that those students, given both practice in solving
analogies and feedback during practice sessions regarding the correct answer and category for each item, performed significantly better than other students in the solving of analogies. Although this was certainly not direct instruction on the solution of analogies, with appropriate, immediate, and relevant feedback during practice sessions, students may have self-corrected their own deduced strategies.

The requirement of given component processes in the solution of analogies has been inferred from the time required to respond with a solution to an analogy. This researcher proposes to investigate whether given component processes in the solution of an analogy may be determined by the presence or absence of the necessary relations in the subject's schemata.

**Story type analogies.** Investigations involving analogies in the form of stories tend to focus on the use of analogies for: (a) problem solving and (b) teaching or learning. Gick and Holyoak (1980), Holyoak, Junn, and Billman (1984), and Perfetto, Bransford, and Franks (1983) determined that the solution to a problem can be developed by using an analogous problem from a very different domain. Subjects ranged from young children to adults, and response formats included both nonverbal (physical) and verbal types.
Holyoak, Junn, and Billman (1984) worked with children from 4-7 and 10-12 years who were given a story analogy describing both a problem and its solution. Then, the subjects were observed as they used materials present in the testing situation to solve a different target problem. Holyoak et al. observed that even preschoolers could use analogies to solve problems. They suggested that if a story analog mapped well onto the problem that even young children were able to generate a analogous solution.

Using a similar technique with older students and a verbal response format, Gick and Holyoak (1980) provided undergraduates with a story analogy, describing both a problem and its solution, and then observed the students verbalize as they found solutions for target problems from other domains. They suggested that one of the major blocks to the successful use of an analogy in problem solving may be failure to notice its relevance to the target problem (i.e., failure to see the similarities between the story and the target problem).

Following in this line of thought, Perfetto, Bransford, and Franks (1983) presented undergraduates with a set of statements to rate, some of which provided clues helpful in the solving of brief problems which were presented next. Although these materials were relatively direct in nature, subjects tended to independently use
the previously acquired information to solve the problems only if they were directly told of the connection between the two tasks. This would seem to suggest that the problem was general rather than an inability to see the analogy (i.e., there is a tendency not to spontaneously compare separate incidents rather than an inability to do so). Additionally, it was observed, that if subjects were told the connection only after completing the first set of materials, they were less likely to use the provided information than subjects who were told earlier. Thus, Perfetto et al. noted that "initial failures to access relevant information can lead to problem-specific deficits in later problem solving performance." (p. 30)

The previously cited studies indicate that students often had to be made aware of and told to use the analogies presented. The existence of the skill of using an analogy strategy to solve problems is of limited value if such a skill cannot be spontaneously activated. At this time this researcher is not aware of any studies which address the issue of how the independent, internally directed use of such a strategy may be developed.

Several studies, on the other hand, have been reported which have investigated various aspects of the use of analogies for teaching and learning. Simons
(1984) reported six experiments with different subjects ranging from fifth-grade students to adults and with different analogies and tasks. He found that the addition of concrete analogies led to improved performance at all levels investigated. The data obtained supported three hypothesized functions for analogies: (a) concretizing (making abstract information more imaginable), (b) structurizing (providing a framework for the construction of a new schemata), and (c) active assimilation (wherein the learner is spurred to become more involved in processing information). In addition, Simons suggested that analogies might be considered efficient reading aids when the extra time investment is compensated for by higher performance.

Earlier studies by Mayer (1975) and Royer and Cable (1975, 1976) also reported the facilitative effect of analogies on the learning of new content materials. Mayer (1975) instructed adults in a learning task (learning a computer programming language) with or without a meaningful model. The presence or absence of a conceptual model was an important variable in instruction. The model seemed to facilitate learning, perhaps by providing a framework already known to the learners to which new information could be related. Similarly, Royer and Cable (1975, 1976) found that preexposure to analogous passages described as either
abstract with illustrations, abstract with analogies, or concrete facilitated learning and memory of a second passage by adults.

Hayes and Tierney (1982) investigated further possible explanations of the role of analogies in the introduction of unfamiliar material. American high school students learned about cricket from text which contained analogies related to baseball. The results provided support for the notion that analogies can aid in the activation of general knowledge (i.e., anything related to the topic) and specific knowledge (i.e., that related to a given instance of the topic).

Vosniadou and Ortony (1983) reported that first-grade and third-grade students could recall and answer questions about texts with analogies better than about texts which contained the same factual information without analogies. This provides additional support for the notion that analogies can be an effective means of transferring knowledge from a well known to a new domain for young students as well as for adults.

Hayes and Henk (1986) found that, for understanding and remembering complex instructional text (learning to tie a knot), illustrations were helpful for both immediate and delayed performance while analogies were helpful for delayed performance. Knot-tying accuracy was the nonverbal dependent variable. Hayes and Henk
suggested that an analogy may be of more use in helping individuals recall information over time than in facilitating initial understanding.

In summary, the findings reported and the hypotheses given are consistent with what is known about long-term memory. Comprehension of new material is facilitated when the learner sees how it is related to and builds upon known information; the more meaningful and better organized material is when it is learned, the more easily it may be retrieved from long term memory.

Theoretical and Instructional Aspects of Analogy

Literature reviewed earlier focused on investigations of how students might be taught to improve their skills in solving analogies. On the other hand, several educators have considered analogies in operation, that is, as strategies for teaching/learning: (a) within a theoretical frame of reference, or (b) functioning in an instructional setting. Although the literature has been written with the current knowledge of analogies in mind and, in that way, is based on the results of research, they are not in and of themselves generally research-based. This literature may be separated into three sections: (a) theoretical considerations, (b) instructional suggestions based on theory, and (c) specific classroom applications of analogy.
Theoretical considerations. Winn (1982) discussed learning and instruction from the point of view of cognitive processes identified as visual (i.e., imaging). He suggested that, in working with an analogy, the required processes of analogical reasoning (i.e., recognizing items and assessing their similarities from features and properties), were visual-type processes.

Reigeluth (1983) developed a portion of a theory of instruction; in particular, he focused on: (a) the kinds of prior knowledge that could be used to help learners acquire, organize, and retrieve new knowledge, and (b) the type of instructional strategies that would help students use available prior knowledge to their best advantage. One of the seven kinds of prior knowledge named was analogic knowledge; the type of instructional strategy component intended to relate this type of prior knowledge and new knowledge was an analogy. Reigeluth indicated that, ideally, analogies should: (a) be familiar to the student, (b) aid the learning of more than one concept, (c) be described before the new knowledge is taught, and (d) be referred to within the lesson. Additionally, places where the analogy breaks down needed to be identified.

Zeitoun (1983) proposed a general model for the use of analogies for teaching scientific concepts. He placed the model within a theoretical framework which
considered: (a) a definition of analogy, (b) explanation of analogical learning, (c) identification of student and instructional variables related to analogical learning, (d) suggestions for evaluating the outcomes, and (e) limitations of using analogies for teaching. He identified factors of the framework that were truly theoretical, had no empirical support, and had not yet been investigated as well as referring to research that supported factors that had already been investigated.

The model proposed by Zeitoun was clearly based upon the theoretical framework presented. It had a sequence of nine steps, the first one optional, and all other steps fed backward and forward indicating continuous revision at all stages. The model was basically that which would be used to design/teach/evaluate an effective lesson modified by specific reference to analogies and consisted of the following steps: (a) measure student characteristics, (b) assess prior knowledge about the topic, (c) examine the learning material of the topic (for built-in analogies) and construct analogies, (d) judge the appropriateness of the analogies, (e) determine the characteristics of the analogies, (f) select a strategy for teaching and a medium of presentation, (g) present the analogy, (h) evaluate outcomes, and (i) revise the stages where necessary.
Winn (1982), Reigeluth (1983), and Zeitoun (1983) have approached analogies from different theoretical perspectives. A common notion seemed to be that, in analogical instructional strategies, associations are made such that the schemata originally activated are not that to which the new information is assimilated; rather, the strategies facilitate the acquisition of new information for which no schemata previously exists in memory. With this in mind, several authors have taken single aspects of what is known about analogies and made suggestions that give practical direction to the practitioner.

Instructional suggestions based on theory. After briefly considering what research had said concerning the role of concrete analogies in learning from science text, Mayer (1983) concluded that the construction of relevant analogies and demonstration of how elements of the topic map into elements of the model might be useful for the student. Suggestions included for constructing analogies and for conducting the mapping process were that the analogy should: (a) allow some or all of the logical relationships in the topic to be generated, (b) include a way of relating each unfamiliar element in the topic to an element in the model, (c) be easy to learn and remember, and (d) not normally be thought of by students on their own.
Also, in a practical vein, Bean, Singer, and Cowan (1985) addressed the issue that explicit teacher guidance was crucial to students' use of analogical reasoning in acquiring new information, as retrieval cues on tests, and on problem solving tasks. They suggested that an analogical study guide might make abstract concepts more imaginable and seemed to mirror a productive thinking process that was effective in complex, unfamiliar materials. To develop and use such a guide, the following was suggested: (a) complete a concept analysis of the content (i.e., decide if the information is important enough for the time and effort involved in this procedure); (b) construct appropriate analogies (i.e., tap into the students' background knowledge to form potential association with new knowledge); and (c) explain and demonstrate to students how they can use the analogy in their reading and in forming retrieval cues for later use.

Finally, Curtis and Reigeluth (1984), Gabel and Sherwood (1980), and Zeitoun (1983) expressed cautions and limitations for teachers concerning the use of analogies in the classroom. When Gabel and Sherwood (1980) investigated the use of verbal analogies in high school chemistry, they determined that a major problem with the use of the verbal analogies was that many students did not understand the analogies being used.
Another limitation suggested was that when the analogy was understood it required motivation and capability to apply the analogy to the chemical situation; that is, students need both desire and ability to use analogies effectively.

Curtis and Reigeluth (1984) added that there is danger either if the analogy is carried too far (it becomes misleading) or if the supposedly familiar content is unknown to the learner (it is useless). Zeitoun (1983) noted also that all the details about a topic cannot be provided by analogies; obviously, the new information is not identical to the known information so other instruction is required to provide technical facts or other details specific to the new topic.

**Specific classroom applications of analogy.** Analogies which match with students' background knowledge may assist them in understanding similar but unfamiliar information. That is, their store of knowledge (schemata), if properly tapped, may provide a framework for assimilating new knowledge. As Tierney and Cunningham (1984) observed, teachers have intuitively used analogy as one way of introducing unfamiliar information in the context of a familiar framework. Teachers, in a variety of content areas and grade levels, have developed some analogies that have been particularly effective and that they have been willing to share with others.
The following represent some of those analogies: (a) Capps (1970) described the presentation of mathematical concepts to elementary students using analogies with language arts applications; (b) Kinach (1985) suggested using analogies to assist high school algebra students in learning to solve linear equations; (c) Hardiman, Well, and Pollatsek (1984) suggested using an analogy to assist in developing the concept of a weighted mean for undergraduate statistics students; (d) Bates (1980) developed a pictorial analogy for the development of the physics concepts of reflection and refraction of waves; (e) Remington (1980) provided concrete and fictional analogies that could be used at the high school and undergraduate levels to develop related concepts of atoms, molecules, conservation of mass, atomic and molecular weight, balancing equations, and so forth; (f) Zegers (1983) presented an analogy using fast food restaurants as a familiar base for developing ecology concepts at the undergraduate level; and (g) Kahn (1983) developed analogies for high school literature students relating driving to an unfamiliar place to reading factual material, and beginning a new friendship to reading fictional material.

In summary, teachers often seem to use analogies to build students' schemata for a topic, as a bridge between old and new. Unfortunately, many students do not of
their own accord integrate old and new knowledge. It often appears that students do not see the similarities between the existing knowledge and the new knowledge. In such a case, the analogy presented would not be facilitative and might even make the concept(s) more confusing. It may also be that many students have not developed an understanding of the characteristics of an analogy, its processes, and how it may be used for learning.

**Summary**

Although this research was directly concerned only with processes involved in solving simple analogies, research investigating the processes and functions of story type analogies was included to provide a more balanced picture of the current research knowledge about analogies. For the same reason, the review concluded with a section focusing on the use of analogies in the instructional setting.

In summary, for the solution of analogies the identification of relations seems to be of great importance. Following Sternberg’s componential theory of analogical reasoning, if both the inference relation and the mapping relation are identified and used appropriately, then the D term should be accurately chosen or produced. The existence and operation of the
relations referred to above have been given some support by mathematical modeling using response time and error rate data. An alternative interpretation would suggest that if either the inference or the mapping relation is identified and properly used, then D should be accurately chosen or produced.

This research into the processes involved in the solution of analogies proposed to: (a) tap into subject's schemata to delineate the inference and/or mapping relations identified and (b) determine the D term chosen or produced. From the data collected, it may be possible to suggest whether: (a) Sternberg's componential theory of analogical reasoning operates for all simple verbal analogies or for an identifiable group of simple analogies, or (b) an alternative interpretation of the process of solution of simple verbal analogies is more applicable.
References


APPENDIX C

PILOT STUDY
Pilot Study

The purpose of the pilot study was to determine the following information:

1. The appropriateness of the analogies for the level of the students.
2. The scoring protocols for the relation lists response data collected.
3. The clarity and best wording for the instructions.
4. The amount of time which should be allowed for various facets of the study.

The sample was obtained from the same school as the sample for the main study. It consisted of one class of eighth-grade students. There was no overlap between the two samples. The time taken for the pilot study was approximately 40 minutes from each of two separate class periods one week apart.

Each subject was required to solve eight analogies and, in a separate task, to identify in writing the relation between the members of 16 corresponding word pairs. The analogies were selected from analogy examples given in Sternberg (1977a). Four of the analogies were classified as functional and four as class naming. In addition, eight distractor analogies were included. Thus, the analogy task consisted of 16 items.
For in any single form of the analogy task, each analogy appeared only once; however, in considering the four forms of the analogy tasks, each analogy was presented in each combination of sequence and format. For each of the two forms of the relations task all the A-B and A-C terms of the target analogies were randomly arranged in a list. The task combinations were randomly distributed to subjects.

On Day 1, in order to counterbalance the two tasks, subjects were randomly assigned to the analogies first or relations first condition. After passing out numbered envelopes containing the required materials, the researcher asked subjects to print their names beside the numbers on the labels on the outside of the envelopes. Subjects were then asked to pull the materials out of the envelopes. They were asked to read the directions on the front of the first activity then to complete the activity as directed. They were told that if they had difficulty understanding the instructions they should ask for help. Subjects were informed that they were working on different tasks and that some would take longer to finish than others. Subjects completed the analogy task in 5 to 8 minutes while the relations task required 18 to 40 minutes. They were instructed that when they finished the first task they were to read the instructions for and to work on the second activity from their envelope. The
task was a content-related mapping task. When all subjects had completed their first task, everyone was instructed to return all materials to the envelopes, and to return them to the researcher. They were told that their second task would be returned the next day.

On day 2, students received the same numbered envelopes as they had had on day one. When all subjects had completed their first task, everyone was instructed to return the first task to the envelopes but to keep the second task.

Upon the completion of the pilot study, those questions that were developed prior to the study were addressed. It was determined that there was no difference in accuracy of analogy solution due to the two categories of analogies selected. The analogies selected were deemed appropriate for the level of the students. The wording of the instructions did not require adjustment.

The pilot study revealed that the analogy and relations tasks had very different time requirements. It also revealed that the length of the relations task was too long. The decision was made to divide the relations task into two halves, each of which would be completed on separate days. The time required for each session was thus limited to approximately 20 minutes. Finally, it was decided that there would be 10 or more days between each of the three required sessions.
APPENDIX D

IDENTIFYING ANALOGICAL RELATIONS
Identifying Analogical Relations

The following procedure was used in order to select: (a) the two categories of analogies, based upon the relations used to build them, and (b) the target analogies to be used in the research. The pool from which the target analogies were selected were those given as examples in Sternberg (1977a).

Six raters (doctoral students) were asked to classify each analogy in a set of analogies provided which consisted of possible target analogies and distractor analogies. The classification was done according to definitions provided them based on Whitley and Dawis (1973). At the same time raters were asked to identify the related pair of terms seen in the analogy stem and to briefly explain in their own words how the word pair identified was related.

The categories of class naming and functional were chosen for the study because they were the only two categories containing four or more analogies from the target pool. For each of these analogies the word pair identified was named as the A-B pair and described as showing the stronger relation. The explanation by the raters of how the words were related was later used to judge the explanations given by the subjects for how members of word pairs were related.
Later, the target analogies with the A-C word pair marked were returned to the six raters. The A-C pair is described as showing the weaker relation. Raters were asked to briefly explain in words how the word pair identified was related. Again, the explanation of how the words were related was later used to judge the explanations given by the subjects for how members of word pairs were related.

Copies of the directions to raters, the definitions of analogical relations, and the instruments used follow.
DIRECTIONS TO RATERS (Task 1)

In completing the following task you will classify completed analogies into five groups according to the relations used to build them. You will also indicate which words are related and verbalize the relation seen. The analogies used as examples as well as those you will classify will all be completed analogies. The first three terms form the stem of the analogy, the fourth term completes the analogy (i.e., is the answer).

Read the definitions and examples provided on page two. Although there are many different categories of analogical relations, the five defined (Whitely & Dawis, 1973) on the following page are those which will be used in this study.

For each of the analogies given:
(a) use an arrow to indicate the related pair of words in the stem,
(b) briefly explain how the words indicated in part (a) are related, and
(c) name the category of relations into which the analogy may be classified using the five categories: (1) functional, (2) class naming, (3) similarity, (4) opposites, and (5) unclassifiable.
Examples are included for your guidance.
ANALOGICAL RELATIONS

**Functional**--The relation between two words is functional if one thing performs some activity on or for the other (e.g., horses : stables :: airplanes : --hangars--).

**Class Naming**--The relation between two words is class naming if one word names some group or characteristic of the object (e.g., robin : daisy :: bird : --flower--).

**Similarity**--The relation between two words is a similarity when the words have the same or nearly the same meaning (e.g., tired : weary :: unhappy : --miserable--).

**Opposites**--The relation between two words is opposites if they have contradictory meanings (e.g., old : young :: bright : --dull--).

**Unclassifiable**-- The relation between two words is unclassifiable if it does not fall into one of the categories identified above (e.g., today : yesterday :: tomorrow : --today--).
EXAMPLES:

#1. scissors : axe :: fabric : --wood--

(a) scissors : axe :: fabric : --wood--

(b) Scissors are used to cut fabric.

(c) functional

#2. beneath : under :: follow : --after--

(a) beneath : under :: follow : --after--

(b) Both beneath and under may be used to represent the same relative location.

(c) similarity

1. (a) attorney : law :: doctor : --medicine--

(b) .................................................................

.................................................................

(c) .................................................................

2. (a) both : either :: and : --or--

(b) .................................................................

.................................................................

(c) .................................................................
3. (a) automobile : road :: train : --track--
   (b) .................................................................
   (c) .................................................................

4. (a) lime : lemon :: green : --yellow--
   (b) .................................................................
   (c) .................................................................

5. (a) hand : foot :: finger : --toe--
   (b) .................................................................
   (c) .................................................................

6. (a) train : engineer :: plane : --pilot--
   (b) .................................................................
   (c) .................................................................

7. (a) riddle : ocean :: puzzle : --sea--
   (b) .................................................................
   (c) .................................................................
8. (a) silence : darkness :: sound : light
   (b) ........................................................
   (c) ........................................................

9. (a) then : now :: past : present
   (b) ........................................................
   (c) ........................................................

10. (a) leopard : tiger :: spots : stripes
    (b) ........................................................
    (c) ........................................................

11. (a) thief : honest :: devil : kind
    (b) ........................................................
    (c) ........................................................

12. (a) word : letter :: paragraph : sentence
    (b) ........................................................
    (c) ........................................................
13. (a) seven : dwarves :: snow : --white--
(b) ................................................................
(c) ................................................................

14. (a) your : my :: yours : --mine--
(b) ................................................................
(c) ................................................................

15. (a) hear : see :: deaf : --blind--
(b) ................................................................
(c) ................................................................

16. (a) divide : double :: multiply : --half--
(b) ................................................................
(c) ................................................................

17. (a) refrigerator : food :: wallet : --money--
(b) ................................................................
(c) ................................................................
18. (a) then : now :: past : --present--

(b) .................................................................

(c) .................................................................

19. (a) merchant : sell :: customer : --buy--

(b) .................................................................

(a) .................................................................

20. (a) cowardice : envy :: yellow : --green--

(b) .................................................................

(c) .................................................................

21. (a) animal : elephant :: cloth : --linen--

(b) .................................................................

(c) .................................................................

22. (a) banjo : pick :: violin : --bow--

(b) .................................................................

(c) .................................................................
23. (a)  music : hymn :: dog : --hound--
(b) ............................................................
............................................................
(c) ............................................................

24. (a)  pistol : bow :: bullet : --arrow--
(b) ............................................................
............................................................
(c) ............................................................

25. (a)  dime : 10 :: nickel : --5--
(b) ............................................................
............................................................
(c) ............................................................

26. (a)  sure : worth :: certain : --value--
(b) ............................................................
............................................................
(c) ............................................................

27. (a)  tree : man :: sap : --blood--
(b) ............................................................
............................................................
(c) ............................................................
28. (a) thunder : lightning :: hear : __see__

(b) .................................................................

.................................................................

(c) .................................................................
In each of the following analogies a pair of words is identified. For the pair of identified words briefly state in your own words the relation seen.

1. automobile : road :: train : --track--

2. refrigerator : food :: wallet : --money--

3. train : engineer :: plane : --pilot--

4. attorney : law :: doctor : --medicine--

5. lime : lemon :: green : --yellow--
6. hand : foot :: finger : --toe--

7. leopard : tiger :: spots : --stripes--

8. word : letter :: paragraph : --sentence--
APPENDIX E

ANALOGY TASKS
INCOMPLETE ANALOGIES -- PART 1: (directions)

One term is missing from each of the following analogies. Examine the choices below each analogy and choose the word that best completes the analogy. Circle the answer chosen. Examples are included for your guidance.

robin : daisy :: bird : ----
   a) petals
   b) flower
   c) blue
   d) summer
   e) white

today : yesterday :: tomorrow : ----
   a) today
   b) then
   c) now
   d) tuesday
   e) future
INCOMPLETE ANALOGIES -- PART 2: (directions)

One term is missing from each of the following analogies. Think about the relations among the three terms given. Then supply the missing term which completes the analogy. Write your answer in the space provided. Examples are included for your guidance.

horses : stables :: airplanes : ________________

horses : stables :: airplanes : __hangars__

riddle : ocean :: puzzle : ________________

riddle : ocean :: puzzle : __sea__
1. refrigerator : wallet :: food : ----
   a) pocket
   b) drink
   c) leather
   d) water
   e) money

2. automobile : road :: train : ----
   a) track
   b) boxcar
   c) ditch
   d) whistle
   e) route

3. bold : shy :: cruel : ----
   a) forward
   b) kind
   c) unfair
   d) gentle
   e) trust

4. year : month :: foot : ----
   a) yard
   b) inch
   c) day
   d) toe
   e) leg
5. lime : lemon :: green : ----
   a) orange
   b) sour
   c) yellow
   d) rind
   e) fruit

6. worm : fish :: crawl : ----
   a) scales
   b) water
   c) float
   d) hook
   e) swim

7. June : summer :: December : ----
   a) month
   b) winter
   c) calendar
   d) coats
   e) snowy

8. leopard : spots :: tiger : ----
   a) brown
   b) stripes
   c) whiskers
   d) claws
   e) sleek
9. train : plane :: engineer : 

10. attorney : law :: doctor : 

11. sugar : lemon :: sweet : 

12. word : letter :: paragraph : 

13. cat : kitten :: dog : 

14. barn : house :: cattle : 

15. hand : foot :: finger : 

16. circle : sphere :: square : 
1. attorney : doctor :: law : ----
   a) patient
   b) patent
   c) court
   d) prescription
   e) medicine

2. hand : finger :: foot : ----
   a) toe
   b) heel
   c) ring
   d) glove
   e) leg

3. bold : shy :: cruel : ----
   a) forward
   b) kind
   c) unfair
   d) gentle
   e) trust

4. year : month :: foot : ----
   a) yard
   b) inch
   c) day
   d) toe
   e) leg
5. refrigerator : food :: wallet : ----
   a) pocket
   b) drink
   c) money
   d) leather
   e) water

6. worm : fish :: crawl : ----
   a) scales
   b) water
   c) float
   d) hook
   e) swim

7. June : summer :: December : ----
   a) month
   b) winter
   c) calendar
   d) coats
   e) snowy

8. leopard : tiger :: spots : ----
   a) brown
   b) stripes
   c) whiskers
   d) claws
   e) sleek
9. train : engineer :: plane : __________________________
10. automobile : train :: road : __________________________
11. sugar : lemon :: sweet : ____________________________
12. lime : green :: lemon : ____________________________
13. cat : kitten :: dog : ____________________________
14. barn : house :: cattle : ____________________________
15. word : paragraph :: letter : ____________________________
16. circle : sphere :: square : ____________________________
1. word : letter :: paragraph : ----
   a) story
   b) line
   c) phrase
   d) period
   e) sentence

2. attorney : law :: doctor : ----
   a) medicine
   b) court
   c) prescription
   d) patient
   e) patent

3. bold : shy :: cruel : ----
   a) forward
   b) kind
   c) unfair
   d) gentle
   e) trust

4. year : month :: foot : ----
   a) yard
   b) inch
   c) day
   d) toe
   e) leg
5. train : plane :: engineer : ----
   a) navigator
   b) cockpit
   c) pilot
   d) controls
   e) driver

6. worm : fish :: crawl : ----
   a) scales
   b) water
   c) float
   d) hook
   e) swim

7. June : summer :: December : ----
   a) month
   b) winter
   c) calendar
   d) coats
   e) snowy

8. hand : foot :: finger : ----
   a) heel
   b) toe
   c) ring
   d) glove
   e) leg
9. automobile : road :: train : _______________________

10. refrigerator : wallet :: food : _______________________

11. sugar : lemon :: sweet : _______________________

12. leopard : spots :: tiger : _______________________

13. cat : kitten :: dog : _______________________

14. barn : house :: cattle : _______________________

15. lime : lemon :: green : _______________________

16. circle : sphere :: square : _______________________
1. **train : engineer :: plane : ----**
   a) navigator
   b) cockpit
   c) controls
   d) driver
   e) pilot

2. **lime : green :: lemon : ----**
   a) yellow
   b) orange
   c) sour
   d) rind
   e) fruit

3. **bold : shy :: cruel : ----**
   a) forward
   b) kind
   c) unfair
   d) gentle
   e) trust

4. **year : month :: foot : ----**
   a) yard
   b) inch
   c) day
   d) toe
   e) leg
5. word : paragraph :: letter : ----
   a) story
   b) line
   c) sentence
   d) phrase
   e) period

6. worm : fish :: crawl : ----
   a) scales
   b) water
   c) float
   d) hook
   e) swim

7. June : summer :: December : ----
   a) month
   b) winter
   c) calendar
   d) coats
   e) snowy

8. automobile : train :: road : ----
   a) boxcar
   b) track
   c) ditch
   d) whistle
   e) route
9. refrigerator : food :: wallet : 

10. hand : finger :: foot : 

11. sugar : lemon :: sweet : 

12. leopard : tiger :: spots : 

13. cat : kitten :: dog : 

14. barn : house :: cattle : 

15. attorney : doctor :: law : 

16. circle : sphere :: square : 
APPENDIX F

RELATIONS TASKS
RELATIONS: (directions)

Examine each of the following pairs of terms and think about how the terms may be related. List as many ways as you can identify for how the terms may be related. Write your answers in the spaces provided. Examples are included for your guidance.

tree - sap

- sap flows through a tree
- sap gives life to a tree
- sap is a necessary element of a tree
- sap is "circulatory juice" for the tree
- a tree is provided nutrients through its sap
- when you cut a tree sap comes out

ring - diamond

- both are playing fields for sports
- related to sports: boxing and baseball
- geometric figures
- shape of similar foods: donuts and beignets
- words used to represent commitment (engagement)
- a ring is set with diamonds
1. train -- engineer

2. leopard -- spots
3. refrigerator -- wallet

4. attorney -- law

5. automobile -- road
6. word -- letter

7. lime -- green

8. attorney -- doctor
1. hand -- foot

2. word -- paragraph
3. automobile -- train

4. lime -- lemon

5. train -- plane
6. leopard -- tiger

7. hand -- finger

8. refrigerator -- food
1. word -- letter

2. refrigerator -- wallet
3. hand -- foot

4. leopard -- tiger

5. lime -- green
6. leopard -- spots

7. attorney -- law

8. train -- engineer
RELATIONS TASK -

1. automobile -- train

2. hand -- finger
3. train -- plane

4. attorney -- doctor

5. automobile -- road
6. lime -- lemon

7. word -- paragraph

8. refrigerator -- food
APPENDIX G

DIRECTIONS FOR SCORING
AND SCORING KEYS
SCORING DIRECTIONS/DETAILS

1. ANALOGY TASK:

right or wrong

recognition: letter answers, no variation
production: use exact word

singular/ plural accepted
synonyms not accepted

Record score for each response on the appropriate data collection form.

2. RELATIONS TASK:

scores 8 to 0

if the required relation is the first stated = 8
if the required relation is the second stated = 7
if the required relation is the third stated = 6
... and so on
if the required relation is the eighth stated = 1
if the required relation is not stated = 0
if the relation is given implicitly in a pair of statements rather than explicitly in one statement -- give the lower score

Record score for each response on the appropriate data collection form.
ANALOGY TASK - FORM I - ANSWER KEY

1 [2-1-2] refrigerator : wallet :: food : --money--  e
2 [1-1-1] automobile : road :: train : --track--  a
5 [5-1-2] lime : lemon :: green : --yellow--  c
8 [7-1-1] leopard : spots :: tiger : --stripes--  b

9 [3-2-2] train : plane :: engineer : --pilot--
10 [4-2-1] attorney : law :: doctor : --medicine--
12 [8-2-1] word : letter :: paragraph : --sentence--
15 [6-2-2] hand : foot :: finger : --toe--

ANALOGY TASK - FORM II - ANSWER KEY

1 [4-1-2] attorney : doctor :: law : --medicine--  e
2 [6-1-1] hand : finger :: foot : --toe--  a
5 [2-1-1] refrigerator : food :: wallet : --money--  c
8 [7-1-2] leopard : tiger :: spots : --stripes--  b

9 [3-2-1] train : engineer :: plane : --pilot--
10 [1-2-2] automobile : train :: road : --track--
12 [5-2-1] lime : green :: lemon : --yellow--
15 [8-2-2] word : paragraph :: letter : --sentence--
ANALOGY TASK - FORM III - ANSWER KEY

1 [8-1-1] word : letter :: paragraph : --sentence-- e
2 [4-1-1] attorney : law :: doctor : --medicine-- a
5 [3-1-2] train : plane :: engineer : --pilot-- c
8 [6-1-2] hand : foot :: finger : --toe-- b

9 [1-2-1] automobile : road :: train : --track--
10 [2-2-2] refrigerator : wallet :: food : --money--
12 [7-2-1] leopard : spots :: tiger : --stripes--
15 [5-2-2] lime : lemon :: green : --yellow--

ANALOGY TASK - FORM IV - ANSWER KEY

1 [3-1-1] train : engineer :: plane : --pilot-- e
2 [5-1-1] lime : green :: lemon : --yellow-- a
5 [8-1-2] word : paragraph :: letter : --sentence-- c
8 [1-1-2] automobile : train :: road : --track-- b

9 [2-2-1] refrigerator : food :: wallet : --money--
10 [6-2-1] hand : finger :: foot : --toe--
12 [7-2-2] leopard : tiger :: spots : --stripes--
15 [4-2-2] attorney : doctor :: law : --medicine--
RELATIONS TASK - FORM A, Part 1

1. train — engineer
   ___a train is driven by an engineer
   ___engineer drives a train
   ___an engineer is the operator of a train
   ___trains are for (used by) engineers
   ___engineer runs the train

2. leopard — spots
   ___a leopard has spots
   ___leopards have spots - they are in a class of ___
       ___spotted animals
   ___spots are characteristic of a leopard (3)
   ___a leopard belongs to the group of animals that ___
       ___have spots (dalmation, cheetah, etc.)
   ___the coat of a leopard has spots
3. refrigerator -- wallet
both are containers - similar
both are containers (2)
storage containers
a holder of other things i.e. container
both used for storage

(function)

4. attorney -- law
attorney practices law
he/she interprets law
attorneys work with laws

5. automobile -- road
automobile uses roads
a road provides a surface for an automobile to travel upon
an automobile travels the road (2)
an automobile rides on a road
6. word -- letter
   ___a word is composed of letters______________________
   ___a letter is part of a word_________________________
   ___a word is a group of letters________________________
   ___letters make up words_____________________________
   ___a word is made up of letters_______________________

7. lime -- green
   ___limes are green (2)_______________________________
   ___a lime is green - characteristic____________________
   ___green is a characteristic of a lime_________________

8. attorney -- doctor
   ___both are knowledgeable in a particular field_______
   ___professionals_______________________________
   ___professional people from specialized schools_______
   ___both are professionals (2)_______________________
   ___both are people - similarities____________________
RELATIONS TASK - FORM A, Part 2

1. hand -- foot
   __at ends of limbs - similar______________________________
   __both are body parts (2)_______________________________
   __extremities of the human body________________________
   __anatomical extremity_______________________________
   __both need extensions for normal functioning__________
   __parts of body (2)___________________________________
   _______________________________________________________________________
   ____(body parts - similar - ID)________________________

2. word -- paragraph
   __both are written communication________________________
   __both on units of communication (speech, writing)_______
   __a word is part of a paragraph________________________
   __subunit and larger unit_______________________________
   __both are made from combining smaller segments_______
   _______________________________________________________________________
   _______________________________________________________________________
   _____________________________________________________________________
3. automobile -- train

__similar function____________________________
__both transportation_________________________
__both are vehicles (transportation)______________
__vehicles for transportation_____________________
__mode of transportation_______________________

4. lime -- lemon

__same class or category - fruit_____________________
__the lime and the lemon are both fruits - _______
_____ associated with a particular color___________
__both are fruit_______________________________
__examples of citrus fruit_______________________
__citrus fruit_______________________________
__both have characteristic colors_______________
__(fruit -5 / color -2 => accept either)________

5. train -- plane

__similar function_____________________________
__both are transportation_______________________
__both are means of transportation______________
__vehicles for carrying large numbers of people__
__mode of public transportation_________________
6. leopard -- tiger
   __same class - cats______________________________
   __two types of cats - known by markings_________
   __both are animals whose fur coloration or pattern_
   ____is described________________________________
   __example of cat family of animals_______________
   __large cats_______________________________
   __both have characteristic markings____________
   __(cats -4 / markings -3 => accept either/both)__

7. hand -- finger
   __fingers are digits on a hand_____________________
   __finger is a characteristic of a hand_____________
   __digits on appendages___________________________
   __a finger is a part of a hand____________________
   __fingers are part of a hand______________________

8. refrigerator -- food
   __you keep food in a refrigerator_________________
   __refrigerator holds food_______________________
   __a refrigerator stores food____________________
   __storage container for the objects_______________
   __refrigerator is a storage place for food_______
1. word -- letter
   ___a word is composed of letters_____________________
   ___a letter is part of a word_______________________
   ___a word is a group of letters______________________
   ___letters make up words____________________________
   ___a word is made up of letters_______________________

2. refrigerator -- wallet
   ___both are containers - similar______________________
   ___both are containers (2)____________________________
   ___storage containers_______________________________
   ___a holder of other things i.e. container___________
   ___both used for storage____________________________
   _____________________________
   __(function)________________________
3. hand -- foot
   _at ends of limbs - similar_______________________________
   _both are body parts (2)______________________________
   _extremities of the human body________________________
   _anatomical extremity________________________________
   _both need extensions for normal functioning___________
   _parts of body (2)____________________________________
   ____________________________________________________
   _(body parts - similar - ID)____________________________

4. leopard -- tiger
   _same class - cats____________________________________
   _two types of cats - known by markings___________________
   _both are animals whose fur coloration or pattern___
   ___is described_______________________________________
   _example of cat family of animals_______________________
   _large cats__________________________________________
   _both have characteristic markings____________________
   _(cats -4 / markings -3 => accept either/both)___

5. lime -- green
   _limes are green (2)____________________________________
   _a lime is green - characteristic________________________
   _green is a characteristic of a lime_____________________
   ____________________________________________________
6. leopard -- spots
   ___ a leopard has spots
   ___ leopards have spots - they are in a class of ___
   ___ spotted animals
   ___ spots are characteristic of a leopard (3)
   ___ a leopard belongs to the group of animals that ___
   ___ have spots (dalmation, cheetah, etc.)
   ___ the coat of a leopard has spots

7. attorney -- law
   ___ attorney practices law
   ___ he/she interprets law
   ___ attorneys work with laws

8. train -- engineer
   ___ a train is driven by an engineer
   ___ engineer drives a train
   ___ an engineer is the operator of a train
   ___ trains are for (used by) engineers
   ___ engineer runs the train
RELATIONS TASK - FORM B, Part 2

1. automobile -- train

   _similar function_______________________________________
   _both transportation_____________________________________
   _both are vehicles (transportation)________________________
   _vehicles for transportation______________________________
   _mode of transportation__________________________________


2. hand -- finger

   _fingers are digits on a hand_______________________________
   _finger is a characteristic of a hand______________________
   _digits on appendages___________________________________
   _a finger is a part of a hand______________________________
   _fingers are part of a hand_______________________________
3. **train -- plane**
   - both are transportation
   - both are means of transportation
   - vehicles for carrying large numbers of people
   - mode of public transportation

4. **attorney -- doctor**
   - both are knowledgeable in a particular field
   - professionals
   - professional people from specialized schools
   - both are professionals (2)
   - both are people - similarities

5. **automobile -- road**
   - automobile uses roads
   - a road provides a surface for an automobile to travel upon
   - an automobile travels the road (2)
   - an automobile rides on a road
6. lime -- lemon

_same class or category - fruit_________________________
_the lime and the lemon are both fruits - _________
________associated with a particular color___________
_both are fruit_____________________________________
_examples of citrus fruit___________________________
_citrus fruit_______________________________________
_both have characteristic colors___________________
_{fruit -5 / color -2 => accept either)__________

7. word -- paragraph

_both are written communication_____________________
_both on units of communication (speech, writing)__
__a word is part of a paragraph_______________________
_subunit and larger unit____________________________
_both are made from combining smaller segments______

8. refrigerator -- food

_you keep food in a refrigerator______________________
_refrigerator holds food____________________________
_a refrigerator stores food_________________________
_storage container for the objects___________________
_refrigerator is a storage place for food__________
APPENDIX H

RAW DATA
## Raw Data

### Code:

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<th>Col</th>
<th>Code</th>
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<td>1</td>
<td>SUBJECT IDENTIFICATION</td>
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<tr>
<td>2</td>
<td>GROUP (1-Student; 2-Adult)</td>
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<tr>
<td>3</td>
<td>RECOGNITION: 2 REL’N; + ANALOGY</td>
</tr>
<tr>
<td>4</td>
<td>RECOGNITION: 2 REL’N; - ANALOGY</td>
</tr>
<tr>
<td>5</td>
<td>RECOGNITION: 0 REL’N; + ANALOGY</td>
</tr>
<tr>
<td>6</td>
<td>RECOGNITION: 0 REL’N; - ANALOGY</td>
</tr>
<tr>
<td>7</td>
<td>RECOGNITION: 1 REL’N; + ANALOGY</td>
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<td>8</td>
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</tr>
<tr>
<td>29</td>
<td>PRODUCTION: WEAKER; + ANALOGY</td>
</tr>
<tr>
<td>30</td>
<td>PRODUCTION: WEAKER; - ANALOGY</td>
</tr>
</tbody>
</table>

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VITA

Catherine Sheard received her Bachelor of Arts from the University of Manitoba in 1968 [major: psychology; minor: botany], her Bachelor of Education from Brandon University in 1972 [science education], her Master of Science (Education) in 1977 from Simon Fraser University [science education], and her Doctor of Education in 1987 from Louisiana State University [Curriculum and Instruction (Reading)]. Catherine has taught high school biology in Manitoba, junior high school science and mathematics in British Columbia, and undergraduate reading courses in Louisiana.
Candidate: Catherine Sheard

Major Field: Curriculum and Instruction

Title of Dissertation: An Investigation of the Inference and Mapping Components of the Componential Theory of Analogical Reasoning

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE

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Kay K. Busa

Mikham Call

William K. Stanley

Date of Examination: April 28, 1987