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The Effect of Cued Recall and Elaboration on Learning with Analogies

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ABSTRACT

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Ann Vergeylen

The purpose of this study was to investigate cognitive processes involved in learning with analogy by the manipulation of identifiable strategy components. The use of cued recall and the elaboration of the analogy were systematically manipulated in order to determine their effect on the use of embedded analogies in written text. It was hypothesized that if analogies are effective at the encoding level then subjects who received analogies but were not cued at recall should perform better than subjects in the control group. Moreover, if analogies are effective at the level of retrieval, subjects who received analogies and were cued at recall should perform better than subjects who received analogies without the cue. The effect of the elaboration of the analogy was also investigated as a possible confounding variable.

The hypotheses as stated could not be investigated. The presence of the embedded analogies hindered the learning performance of the subjects, thereby confounding any positive effect which could result from the analogies. An interaction between the teaching strategy and the content of the experimental material was discovered which resulted in

an experimental artifact which was in direct opposition to enhancement strategies.

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CHAPTER ONE

Introduction

Educational reseachers have examined a variety of instructional design strategies that are used to maximize the effectiveness and meaningfulness of instruction. One of the most prevalent strategies found in the literature of instructional design is to relate what is being learned to what the learner already knows. The use of analogy is one such means which relates new information to the learner's prior knowledge. "Used as a teaching strategy, analogies provide a comparison which can explain something difficult to understand by pointing out its similarities to something easy to understand or already understood" (Zeitoun, 1984, p.107).

There is an indication that instruction with analogies is effective, although it is not really known why (Simons, 1984). This problem will be addressed in the present study. It is not the intention of this research to determine whether or not an analogy is an effective learning strategy, but rather to investigate why the strategy is effective.

Since the use of analogies in learning material is widespread, the results of this research have implications for the practice of instructional design. A theory of instruction should be able to prescribe when the use of analogy is optimally effective. This study is intended to increase our knowledge concerning the effectiveness of analogies by investigating encoding and retrieval operations in the learning process and therefore has prescriptive implications.

The investigative procedure which will be used adheres to what Levin (1986) describes as the 'component analysis' approach. This approach aims to determine why a particular learning strategy is effective by the systematic manipulation of identifiable components of the strategy in question. By identifying and localizing the effects of a strategy, specific learning outcomes which result from the manipulation of strategy components may be identified. Levin suggests reseachers routinely conduct a component analysis of the learning processes and learning strategies they are investigating. The objective of the analysis is for "the researcher to map strategy components onto both presumed cognitive processes and learning outcomes" (Levin, 1986, p.10).

The particular learning strategy which is investigated in this study is the use of embedded analogies in a text. More specifically, it examines the extent to which analogies enhance the acquisition of new information relative to the degree they facilitate the retrieval of information. Based on a review of the literature, it appears that the function of analogies at the information retrieval stage has received minimal attention.

Usage of the Term

Several authors have attempted to convey the meaning of analogy in an instructional context. Tierney and Cunningham (1984) state: "Analogy may be defined as an expositional method for comparing sets of information which are similar enough in essential respects to permit transportation of attributes across sets, usually from familiar to unfamiliar information" (p.613). In general, there is agreement that an analogy conveys important similarities with the knowledge to be learned and, furthermore, that the topic and analogue belong to different conceptual domains.

According to Gentner (1983), an analogy is distinguished from other forms of comparisons by the predominance of relational attributes which two domains have in common. For instance, an overlap in both object and relational attributes is an example of literal similarity. The comparison of the K5 solar system to our own solar system is a literal similarity. An analogy, on the other hand, is characterized by few or no common object attributes and many relations between two domains. An example of an analogy is "The atom is like our solar system". For Gentner, an analogy is "an assertion that a relational structure that normally applies in one domain can be applied in another domain" (p.156).

For instructional purposes, Zeitoun (1984) describes four basic components that an analogy should contain. The topic, also called the target domain, is the material which is to be learned. The analogue is the familiar, visualistic material which is used to facilitate the learning of the topic. The analogous attributes are the corresponding attributes shared by both the topic and the analogue. According to Zeitoun, there should be at least one analogous attribute which is shared, otherwise, the term "analogy" is not applicable. Finally, the irrelevant attributes refer to those attributes which the topic and the analogue do not share. The irrelevant attributes form part of the "nature" of an analogy in that if all attributes were identical or similar there would be no analogy.

A closely related concept is the metaphor. Traditionally, a metaphor takes the form of an implicit comparison as in "man is a wolf". Generally speaking, metaphors are really "implicit analogies" (Ortony, 1980). Gentner (1983) finds no real difference between a metaphor and an analogy in that "many (perhaps most) metaphors are predominantly relational comparisons, and are thus essentially analogies" (p.162). From an even broader perspective, "any expression of similarity or resemblance can be called an analogy" (Miller, 1979, p.225).

In that an analogy can convey any form of comparison, this is reflected in the somewhat arbitrary use of the term in the research literature. For instance, studies which have investigated learning with an analogy have done so under the label of various instructional strategies. An analogy can be considered as a concrete model of a phenomenon (see Mayer, 1983), or as an elaboration technique (see Mayer, 1980; Reder, Charney & Morgan, 1986). The location of the analogy in the text also varies. The analogy can be placed at the beginning of the learning material, independent of the presentation of the topic (see Simons, 1984) or several analogies can be embedded in the text (Reder, et al., 1986)

In this study the term "analogy" will be used as an all inclusive term; however, the appropriate distinctions will be made in keeping with the various usage of the term.

The Use of Analogy in Teaching

The use of analogy in teaching is based on the accepted teaching practice that new concepts can be taught more easily if they are related to existing knowledge structures. It is assumed when teaching with analogy that the learner has already acquired the knowledge which is addressed in the analogy. If the learner does not possess the knowledge which is addressed, the analogy should be easy for the learner to acquire. An unfamiliar or difficult analogy may distract the learner from the topic to be learned since the learner is required to understand both the analogue and the topic (Zeitoun, 1984). Schon (1963), points out: "learning by analogy does not in itself involve the formation of a new concept; it comes rather from an observation of similarity in concepts already formed" (p. 40). In other words, it is not possible to "use" an analogy if the similarity between the two concepts has not yet been conceptualized.

Sticht (1979) emphasizes a further risk in the use of analogy in written material:

> The use of metaphor in written text is a particularly hazardous venture for both the teacher and the reader. Typically, the teacher as writer has only the most global notions of who the potential readers might be. Thus, when transferred to the written language, particularly in the mass production of textbooks, metaphors, like other more-or-less "context-bound" figures of speech, run the risk of leading to misunderstanding because a large number of readers may not share the required experiences for receiving the large chunks of information to be transferred by the metaphor. Typically, the author is not available, and so readers cannot resolve ambiguities through question-and-answer techniques. (p. 477-478)

When using analogies there is also the possibility that the learner may extend the analogy beyond what was intended by the teacher. Analogical learning requires that the student be able to 1) transfer information which is analoguous to the topic and 2) isolate the irrelevant attributes of the analogue from that of the topic (Zeitoun, 1984). In lieu of this consideration, Webb (1985) proposes that the instructor make greater use of the limitations of an analogy and, at the very least, point them out to the students. If the students have themselves correctly understood the analogy and the topic, they should be able to point out some limitations of the analogy.

The construction of analogies thus requires "careful planning and a clear sense of students' day-to-day experiences" (Bean, Singer & Cowan, 1985, p.247). When used correctly, however, analogies can provide an effective technique to maximize the transfer of learning. According to Mayer (1983), analogies provide the learner with a familiar system which can then be used for interpreting and integrating new information. The use of analogies in this manner enhances the acquisition of new material. Relating new knowledge to prior knowledge is also important for the retrieval of information because of the additional links which are created in memory (Gagné, 1978).

Purpose of This Study

This investigation will attempt to determine whether the effect of analogies is greater at the level of encoding or at the level of retrieval. The material will consist of a written text which describes computer concepts with analogies woven in the text. The control group will have the same text but without the analogies.

The present study also distinguishes between "elaborated" and "non-elaborated" analogies. An analogy can constitute a form of elaboration provided by the author, whereby an elaboration is "any information that supports, clarifies, or further specifies the main points of a text" (Reder, et al., p. 64). To the knowledge of this author, the distinction between elaborating and not elaborating an analogy has never been made within the framework of an empirical study. The only reference found in the literature is by Dreistadt (1968) who refers to analogies that are elaborated upon in a discussion of scientists who, in the past, have elaborated on an analogy as a means of gaining insight into a scientific phenomenon. This study attempts to investigate whether the presence or absence of elaboration with respect to an analogy interacts with the process of the acquisition or retrieval of new information.

CHAPTER TWO

Literature Review

Theoretical Perspectives

Various theoretical views attempt to explain why learning with analogies is effective. The most popular explanations rely on the theory of the schema in order to explain the process of learning with analogy. The origin of schema theories is traced to the viewpoint originally proposed by Bartlett (1932) in order to account for the incompleteness and distortions of subjects' recall for complex stories. According to current schema theorists, what is stored in memory is heavily determined by the existing knowledge framework or schemata: a guiding schema "selects and actively modifies our experience in order to arrive at a coherent, unified, expectation-confirming and knowledge-consistent representation of an experience" (Alba and Hasher, 1983, p. 203).

Rumelhart and Norman (1981) refer to the learner's schemata to describe learning with analogy. According to the authors, when learning occurs new information is encoded in terms of instances of the concept represented by existing schemata. The formation of new information by analogy involves the creation of a new schema modeled on the existing schema. Accordingly, the authors point out that when people learn, they often create models and make plausible inferences with situations they already understand. The ability of the human system to apply knowledge learned in one domain to another is characteristic of its adaptive nature. According to the authors, "the most common way in which people apply knowledge learned in one domain to another is through analogical reasoning" (p.343). Learning by analogy, therefore, allows people to learn a great deal about a new situation in that inferences can be made based on the existing schema.

The structure-mapping theory of analogy (Gentner 1983, Gentner and Toupin, 1986) emphasizes the relational structure analogies have in common with the target domain. Learning with analogy involves mapping the relationships, as opposed to the object attributes, from one domain (the base) onto another (the target). The mapping process is guided by the principle of "systematicity". According to the principle of systematicity "a predicate that belongs to a mappable system of mutually interconnecting relationships is more likely to be imported into the target than is an isolated predicate" (Gentner 1983, p.163). Hence, it is predicted that higher order relationships will be mapped onto the target domain before lower order relationships. Accordingly, the authors found that adults tend to judge analogies as more apt if they share a systematic relational structure with the base domain as opposed to attributional similarities. Adults also tend to ignore the attributes of an analogy in their interpretation of analogies. (Gentner and Toupin, 1986).

Holland, Holyoak, Nisbitt and Thagard (1986) are critical of the structure-mapping theory and claim that the systematicity principle is basically a syntatic analysis of the analogue and is irrelevant to the process of understanding the analogy. According to Holland, et al. Gentner's analysis, furthermore, fails to effectively distinguish between relations that are transferable to the target domain from those which are not transferable.

The use of analogy as a learning strategy has also received attention in terms of the "meaningful learning" hypothesis (Mayer, 1982). Meaningful learning occurs when new information is integrated in the context of existing knowledge. In order for this to occur, the learner must have the prerequisite knowledge in long term memory, and the knowledge must be activated and transferred to active consciousness. One means by which activation of prior knowledge can be obtained is through the use of analogy (Reigeluth, 1983).

Finally, the use of analogy in learning can be described as an elaborative activity. According to the "encoding elaboration" model (Bradshaw and Anderson, 1982) recall for material which is supported with related facts is superior to material which is not supported because alternate retrieval paths are created by the elaborations. This improves recall for learned material because people may be able to infer the material studied from the presence of the remaining elaborations.

To summarize, most theoretical accounts of learning with analogy imply, in one form or another, that new information is integrated within the relational structure established by the analogy. Either it is easier to learn the new information because the structure is already acquired and there is less information to assimilate (Rumelhart and Norman 1981; Gentner, 1983) or the new information is more meaningful to the learner as a result of its integration with prior knowledge (Mayer, 1982).

Empirical studies done on the use of analogy basically support these explanations. As previously mentioned, however, there is a lack of consensus by researchers as to what constitutes an analogy. With this consideration in mind, analogies which are presented to subjects at the beginning of the learning material, independent of the topic to be learned, will be discussed first.

The Analogy as an Advance Organizer

According to Ausubel and Fitzgerald (1961) advance organizers consist of "ideational material (both similarities and differences) at a high level of abstraction, generalizability, and inclusiveness" (p.267). The role of the organizer is to provide helpful "ideational anchorage" or "scaffolding". In cases where the learning material is related to prior knowledge, the organizer increases the discriminability and hence retention of the passage to be learned.

The benefit of an advance organizer varies with the level of the learner's prior knowledge. In one study, (Ausubel and Fitzgerald, 1961) subjects were presented with a passage describing Christianity two days before learning a passage on Buddhism. The authors found the advance organizer facilitated retention only for those subjects who had a below average knowledge of Christianity.

While Ausubel and Fitzgerald claim that an advance organizer should consist of information at a high level of abstraction, Royer and Cable (1976) used concrete, specific models as advance organizers. They presented subjects with an initial passage which was characterized as either abstract with illustrations, abstract with concrete analogies or concrete. These subjects recalled significantly more of the target passage than subjects who received an abstract passage or control passage as the initial passage. According to the authors, the presentation of an initial concrete passage allowed the content of the target passage to be assimilated into the knowledge structure established by the initial passage.

Royer and Cable (1976) claim that in order for transfer of learning to occur, two conditions must be met. The initial passage must provide a "knowledge bridge" between what the subject already knows and the target information, and the target passage must be difficult to comprehend. The Ausubel and Fitzgerald (1961) study supports both of these claims as does the study by Royer and Cable.

Learning outcomes. In a series of experiments, Simons (1984) investigated three functions of learning with analogy - concretizing, structurizing, and active assimilation - as explanations for their effectiveness. The author developed analogical passages which were designed to help secondary students learn about concepts of electricity. Subjects in the experimental group received the analogical passage prior to receiving the learning material. In support of the concretizing function of analogies, the author found a significant aptitude X treatment interaction on the visualizer-verbalizer dimension; visualizers tended to score higher on a comprehension test when learning with analogies whereas verbalizers performed better without analogies. Although the effect was not consistent over repeated trials, the results give credence to the concretizing function of analogies. In support of the structurizing function of analogies, the author found that subjects in the experimental group showed a better knowledge than control subjects of the relationships among the concepts as measured by a relation test. Evidence for the function of active assimilation was also found. According to this explanation, analogies serve to stimulate students to actively integrate the new information with previously learned information. Measures of learning which are influenced by the integrative process, (e.g., a transfer test) should result in higher performance for subjects learning with analogy. Accordingly, the author found that measures of comprehension, "transfer of learning" (Simons, 1984), and knowledge of relations were higher for the subjects in the experimental group.

According to Mayer (1982), learning with analogy enhances higher level learning but not the recall of specific information. The author found that presenting a concrete analogy of a computer before having subjects read a manual on computer programming resulted in better recall of conceptual information and far transfer (putting information together in a novel way). Subjects who were not given the model, however, performed as well or better on test items involving single pieces of information.

According to the findings of Simons (1984) and Mayer (1982), a qualitatively different type of learning outcome is achieved with the presentation of analogies. Subjects who received analogies displayed a better knowledge of the relationships among the newly learned concepts and tended to acquire a higher level of knowledge. Mayer, however, has repeatedly found higher level learning with the use of various learning strategies including model elaboration and advance organizers (Mayer, 1980). To attribute higher level learning to the use of a particular learning strategy, in this case the use of analogy, is not warranted in light of this consideration.

A study done by Hayes and Tierney (1982) is the most comprehensive performed to date on the effects of learning with analogy. The authors controlled for their subjects' prior knowledge and interest in the topic area, varied the relevance of the initial passage, and varied the type of analogy used in the target passage. In their study American high school students learned about the Australian game of cricket by relating the game to baseball. They presented their subjects with an initial passage on baseball in order to invoke concepts which would be useful for learning about cricket. The authors also included embedded analogies as a variable in the target passage. These analogies were specific comparisons made between the game of baseball and cricket. It was reasoned that if analogies provide a link between prior knowledge and new knowledge categories, analogous information which explicitely compares the two games should result in greater transfer of information than information which does not make explicit comparisons.

The authors found that the subject's prior knowledge of baseball and the provision of an initial, instructional text on baseball accounted for the most variance. The specific provision of analogies had a modest effect on learning with the less knowledgeable students benefitting the most. The authors interpreted the results as providing strong support for the activation of general knowledge with the use of analogy and modest support for the activation of specific knowledge.

To summarize, it appears that when the learner's prior knowledge of the target information is considered, the increase in learning as a result of the provision of the analogy is positively affected by the learner's prior knowledge. Ausubel and Fitzgerald (1961) also found a positive correlation across all treatment groups between their subjects' prior knowledge and their performance. Notwithstanding the effect of prior knowledge, the results of Hayes and Tierney indicate that the provision of an instructional text, which serves to highlight relevant knowledge prior to learning a related topic, is an effective means to promote learning. The specific provision of analogies, however, was not found to significantly enhance learning for all subjects.

Differences in Study Time. A reasonable explanation as to why analogies placed at the beginning of the learning material enhance learning, is that the higher performance is a direct result of differences in study time. Since more time is spent studying material which includes analogies, experimental subjects have the advantage of time over control subjects. Simons (1982, 1984) investigated the efficiency of learning with analogy by taking into account the effects on reading time. According to the author, analogies can produce a lengthening effect, apart from the fact that extra words are involved, because analogies stimulate a different, deeper and slower kind of processing in the reader. On the other hand, the inclusion of analogies may result in a faster reading tempo because the reader understands the text more quickly and easily.

The results on reading time were found to differ according to the age of the learner. Secondary school students spent more time reading for the first time a text with analogies than those who did not receive the analogies (Simons, 1982). With college students, no time differences were found between subjects who read the analogies and the text and subjects who read only the text. Although the experimental subjects had more words to read, the time spent reading the analogy was apparently compensated for by the shortening effect of the analogy which resulted in equal study time.

In the studies discussed so far, analogies were used as a concrete model of a phenomena and were presented in an initial passage, prior to the target passage. Analogies, however, can take other forms such as when several analogies are woven in a text. In this respect analogies can serve to elaborate upon the information presented in the text and take on the characteristics of an elaboration technique.

Research related to the effects of elaboration will now be discussed.

The Effect of Elaboration on Learning

An elaboration is defined as "any information that supports, clarifies, or further specifies the main points of a text" (Reder, et al., 1986, p.64). Elaborations are considered to enhance learning and recall because they create more connections to the learner's prior knowledge and provide multiple retrieval routes to the essential information. Information which has been elaborated upon is more likely to be retrieved because of the greater number of alternative retrieval paths which have been created; if one set of connections is forgotten, it may be possible to retrieve the desired information via an alternative retrieval path. Furthermore, if the learner forgets the target information, it may be possible to infer or reconstruct the missing information since there are more cues which can be referred to from the remaining elaborations. An assumption of the model is that in order for information to be retrieved, it must be well integrated with the elaborative information during the encoding phase. (Stein, Littlefield, Bransford & Persampieri, 1984).

Not all types of elaborations have been found to be effective. Bradshaw and Anderson (1982) manipulated the type of sentence elaboration given to subjects. The authors found recall performance for the central fact expressed by the sentence best when it was supported by related facts, next best when no elaboration was provided, and worst when studied along with unrelated facts. Stein, et al., (1984) found that only elaborations which serve to reduce the arbitrariness of relationships among the concepts facilitate sentence recall and recognition. For example, subjects were more likely to remember, given a cued recall test, the sentence: "the short man picked up the broom to sweep the floor" than the sentence: "the short man picked up the broom to operate the light switch".

Research using prose passages has not been consistent by way of supporting the use of elaborations to enhance learning. In a much cited study, Reder and Anderson (1980) found that students who read elaborated prose taken verbatim from college textbooks consistently performed worse than did students who studied summaries that just contained the main facts. One possible explanation for these findings, according to the authors, is that the "summary group" had an advantage because it allowed the reader to focus full attention on the essential facts, or those facts which were tested for. Studying the elaborated text, on the other hand, impeded learning because reading the elaborations reduced the amount of time spent learning the main points of the text. When the authors equated study time for the main points of the text, subjects were still better off when they studied the material without the supporting details (Reder and Anderson, 1982). It seems that studying details does not increase the memorability of the main points of a text but rather, inceases the burden of the material to be learned.

More recently, Miller and McCowan (1986) found that the _free_ recall of target propositions differed reliably as a function of the amount of elaboration. The authors varied the elaboration of the target sentence in two ways: the "unelaborated version" provided elaboration for the topic sentence but not the target sentence while the "elaborated" version elaborated the target sentence. The authors controlled for the "levels effect" by holding constant the position of the target proposition in each paragraph. Briefly, the levels effect is a well documented phenomena which predicts that the superordinate propositions, or most important propostions, will be remembered with greater frequency than the less important details. The authors found that the elaborated group recalled more of the target propositions than subjects in the unelaborated group.

Based on the contradictory nature of the research on author-provided elaborations, it appears that the quality of the elaborations which are provided is of utmost importance in the subjects comprehension and/or recall of new information. Elaborations which produce a relevant context for the integration of new information are more likely to enhance recall than elaborations which provide extra information by way of elaborating on related details. The importance of the quality of elaborations is also evident with respect to learner-generated elaborations. Wang (1983), in a paired associate learning task, found that fast learners were able to produce more effective elaborators than slow learners and more quickly. The elaborations generated by fast learners better reinstated the conditions of the original learning context and were easier to maintain throughout the learning trials.

Notwithstanding the issue of the quality of elaborations, it is worth noting that the quantity of the elaborations which are provided by the author or generated by the learner is also relevant. Following the explanation taken by the encoding elaboration model, the probability of the recall of information appears to increase as a function of the number of retrieval paths created. Mandl and Ballstaedt (1982) caution against this approach by pointing out that an upper limit must exist to the number of elaborations which can be considered useful: "If someone elaborates endlessly, his\her performance at reconstruction would probably be worse than that of a learner with less elaborative processing" (p.485). According to results obtained by Mandl and Ballstaedt, there is an inverted U-shape relationship between the number of elaborations generated by learners and their recall performance; subjects who elaborate a great deal or who elaborate very little do not perform as well as subjects with an average number of elaborations.

<u>The use of cued recall</u>. The use of cues in order to reinstate the original learning context is not unusual in studies of learning and recall. Fisher and Craik (1980) have suggested an elaborate encoding structure establishes a richer trace, but that the elaborate encoding will only be effective to the extent that the encoding context is reinstated at retrieval.

Schustack and Anderson (1979) found that the provision of a cue at both study and test times enhanced performance. The authors presented subjects with a biographical passage about a fictional character which was analogous to a famous person. Subjects in the experimental group were made aware of the analogy between the fictional character and the famous person before reading the text, while control subjects were not aware of the analogy. Best recognition for the text resulted when the famous person was identified at both study and test times; the identification at study or test time alone interfered with memory relative to no identification.

Objectives of the Study

This investigation attempts to determine whether the effect of analogies is greater at the level of acquisition or retrieval. The distinction between acquisition and retrieval processes is based on the manipulation of experimental variables rather than a particular theoretical orientation. In order to distinguish between encoding and retrieval operations, the presence of analogies in the target passage and the presence of a cue at recall were varied. It is proposed that if analogies are effective at the encoding level, subjects who received analogies in the target passage but were not cued at recall should perform better than subjects in the control group. Moreover, if analogies are effective at the level of retrieval, subjects who received analogies and were cued at recall should perform better than subjects who received analogies and were not cued at recall.

It is assumed in this design that subjects who were not cued at recall would not employ the same strategy as those subjects who were cued at recall, that is recall the analogy in order to answer the questions on the post-test. A checking procedure was therefore employed in order to determine whether subjects not given cued recall actually recalled the analogy on the post-test. This procedure took the form of having subjects recall the analogy which was presented in the text upon presentation of the concept.

Based on the work of Simons (1986) who found that subjects were unable to even match the analogy with the concepts, it was expected that subjects would not be able to recall the analogies in order to answer the questions on the post-test. In consideration of this finding, subjects in this study were cued at recall with the corresponding analogy used in the learning material. As indicated by the Anderson and Shustack study (1979), in order to receive the benefit of the analogy subjects must be cued at both encoding and retrieval. If analogies facilitate the retrieval of information through the provision of extended retrieval paths, then subjects should be able to retrieve the information when provided with the analogy as a cue.

The learning material consists of a written text which describes computer concepts with analogies embedded in the text. The control group received the same text but without the analogies. This is in contrast to the bulk of previous research which presents subjects with analogous information in an initial passage prior to presenting the target passage. One difficulty with this previous research is that the facilitative effect found with analogies is confounded with the effect of the analogy presented in the form of an advance organizer. In contrast, the present study attempts to eliminate the confounding effect of advance organizers by presenting subjects with a single text and embedding the analogies in the text.

A further concern in this study is the effect of elaboration and its interaction with the process of the acquisition and retrieval of information. Upon developing the learning materials, it was realized that analogies can either elaborate on a given concept or not provide elaboration. A distinction was therefore made between elaborated and non-elaborated analogies.

CHAPTER THREE

Method

Research Design

The design was a 2 X 2 X 2 incomplete block design. There were two between-group factors: the presence or absence of embedded analogies and cued or non-cued recall. The incomplete factor was the presence or absence of elaboration with respect to the analogy in the "With Analogy" conditions only: In the "No Analogy" conditions it follows that since there are no analogies, there cannot be elaboration with respect to the analogy (see Figure 1). Measures of learning performance and affective data served as the dependent variables. Several measures of learning performance were taken; these included an overall score on the post-test, a score based on questions which refer to analogies in the text, and a score based on questions which do not refer to analogies.

Subjects

Thirty-four students enrolled in the Office Systems Technology program at a Montreal English-speaking CEJEP participated in the study. The subjects in this experiment were in their second year of study and had followed a course in word processing and an introductory course in microcomputers. All of the subjects were female. The

Figure 1. The Experimental Design

	with cued recall	without cued recall
with analogies	with/without elaboration	with/without elaboration
without analogies		

subjects participated in the study as part of their course requirements.

<u>Materials</u>

The experimental text was prepared by the experimenter and explained computer concepts such as ROM and RAM, speed of procesesing, and how programs are processed. The analogies were adapted from <u>Inside the IBM PC</u> by Peter Norton and <u>The Women's Computer Literacy Handbook</u> by Deborah Brecher. An analogy was selected for the experimental text by the experimenter according to two criteria: The comparison between a computer concept and the topic was easy to understand, and the topic referred to a familiar, every-day occurence.

Two versions of the text were prepared: The "with analogy" version (see Appendix 1) had analogies woven in the text while the "no analogy" version (see Appendix 2) presented the same concepts without the analogies. As much as possible, the no analogy version differed from the with analogy version of the text only in terms of the presence or absence of analogies. There were 2,066 words and 1,610 words respectively in each version.

Two types of analogies were distinguished by the experimenter: "elaborated" and "non-elaborated". Non-Elaborated analogies are in the form of a simile as in: "The operating system is like a traffic cop who gives instructions to motorists". Non-elaborated analogies do not elaborate on the information which is provided by the analogue. Analogies which are deemed as elaborated, on the other hand, give an explanation of the concept in both the analogic situation and the topic situation. An elaborated analogy, for example, compares the process of converting the programming language into machine language with the process of translating a speech into a foreign language. The method of conversion is explained in the topic situation and also in the analogic situation. In the no analogy text, the analogic situation was deleted from the text and the explanation was in terms of the topic situation only.

The experimental text for the control group does not have any analogies. Non-elaborated analogies were deleted from the text. Elaborated analogies were also deleted and the explanation which remained was in terms of the topic situation only.

The post-test consisted of short answer questions which required the student to explain a concept or process in two or three sentences. Questions on the post-test measured the subjects comprehension of the material as proposed by Anderson (1972). Accordingly, the questions paraphrased the material in the text to ensure that the subjects comprehended the ideas and did not just recall the wording at a surface level.

The post-test varied according to the treatment condition. Under the cued-recall condition, subjects were prompted in questions which referred to analogies. In the cued analogy group the prompt referred the subjects to the analogy which had been presented in the experimental text (see Appendix 3). For the no analogy cued group, the prompt suggested to subjects they think about a particular concept. For example, subjects were given the prompt: "It may be helpful to think of the language which is used in cooking when answering this question". In the no-cue condition, the same questions appeared but without the prompt (see Appendix 4). Subjects who were not cued on the post-test yet received the analogies in the text were furthermore tested for their recall of the analogies used in the text as a checking procedure (see Appendix 5). This consisted of free recall of the analogy upon presentation of the learned concept. Finally, measures of the subjects' attitude towards the text and questionnaire were collected along with their degree of perceived familiarity with the material.

Procedure

Prior to conducting the experiment, the author prepared a questionnaire which was handed out to the subjects by the teacher. The purpose of this questionnaire was to assist the author in writing the experimental material. Based on a review of the results of the questionnaire, the content of the material was revised to match the subjects' level of knowledge as much as possible.

Two weeks before the experimental testing, a pilot study was carried out on 15 volunteers who were in the same year as the subjects. Results of the pilot test indicated that the level of the material and questionnaire was suitable for the subjects. The to-be-learned material was also submitted to a content expert who reviewed both versions of the material for clarity of expression and content.

The actual experimental testing was carried out by the teacher during class time. Random assignment to each treatment condition was achieved by the teacher randomly handing out the experimental materials. Subjects were told they were participating in a study to investigate how people learn about computers. The teacher handed out the materials in an envelope and instructed the students when to start. The subjects were told to identify themselves only by the last four digits of their telephone number for follow-up purposes.

The subjects were asked to read the experimental passage carefully and as often as they required. A time limit of 20 minutes was imposed; however none of the students required this much time. Following the text there was an interpolated task which required subjects to do two mathematical operations. Subjects then completed the post-test. One week later the same post-test was administered to the subjects under the same conditions.

CHAPTER FOUR

Results

Scoring Procedure

Scores on the post-test were based on criteria developed by the experimenter (see Appendix 6). Each short answer was worth two points and one point was provided for partially correct answers. Overall, subjects answered 38% of the questions correctly. This was surprising given the good results of the pilot test study.

While developing the criteria, the experimenter had to make what were thought to be subjective decisions regarding the validity of the subjects' answers. This was largely due to the writing skills of the subjects. Initially, criteria were developed which resulted in inconsistent scoring procedures and could not produce a high inter-rater reliability score. The criteria were then rendered more precise and included more examples than the original criteria. An inter-rater reliability score of 90% was calculated using the final criteria.

While scoring short answer questions reflects a more judgmental process than scoring, for example, multiple choice questions, the decision to include short answer questions as the dependent variable was deliberate and was based on the assumption that the recall of information reflects different cognitive processes than the recognition of information. Research has suggested that the activation of the learner's schema, as was intended by the manipulation of variables in this study, is more advantageous in the recall of stimulus items than in the recognition of stimulus items (Alba and Hasher, 1983).

To establish the dependent variables, a composite score was obtained for each dependent variable based on selected questions on the post-test. An initial analysis of the composite scores indicated the data were normally distributed and met the assumptions of inferential statistics. When necessary, composite scores were converted to percentage scores so that variables of equal weights could be compared. Recall on the delayed post-test was extremely low and, given the floor effect, these results will not be further discussed.

<u>The Effects of Analogy and Type of Recall on Performance</u>

An analysis of variance with the use of analogy and type of recall (cued or uncued) as between group factors was performed on the total raw score of subjects. A significant main effect was found for the use of analogy F (1,30) = 5.58, p <.05. Contrary to what was expected, subjects who did not receive the analogy performed significantly better on the post-test than subjects who did receive the analogy (see Table 1). The following analysis will attempt to explain why subjects who received the analogies were at a

Table 1

Means and Standard Deviations of Total Raw Score

	With Cue		Without Cue	
	M	SD	M	SD
With Analogies(a)	12.33	5.38	6.78	4.1
Without Analogies(b)	13.88	3.76	13.75	7.1

(a) $\underline{n}$ = 9 for each group
(b) $\underline{n}$ = 8 for each group

disadvantage. A second analysis was completed on achievement scores from responses to questions which dealt with analogies. A significant interaction was found between the use of analogy and type of recall $F(1,30) = 5.71$, $p < .05$. Figure 2 illustrates the interaction and the means are presented in Table 2. The Tukey test indicated that subjects who received the analogy with the cue performed significantly better than subjects who did not receive the cue with the analogy, F_{comp} $(3,30) = 6.49$, $p < .05$. The presentation of the cue was clearly instrumental in retrieving relevant target information. In the No Analogy conditions, the effect of the cue was not significant. Although the performance of the control group resulted in the highest mean ($M = 10$), there were no significant differences between the performance of the control group and the With Analogy, With Cue group ($M = 8.44$). The control group, however, performed significantly better than the group which received only the analogies, F_{comp} $(3,30) = 8.74$, $p < .05$)

The analysis of the post-test scores in the control group suggests a possible explanation for the detrimental effect in subjects' performance with the use of analogies. Although no analogies were actually included in the text for the control group, a correlated t-test on the percentage scores indicated that questions with analogies ($M = 50\%$) resulted in significantly higher performance than questions

Figure 2. The Interaction of the Analogy and Type of Recall on Questions which Dealt with Analogies

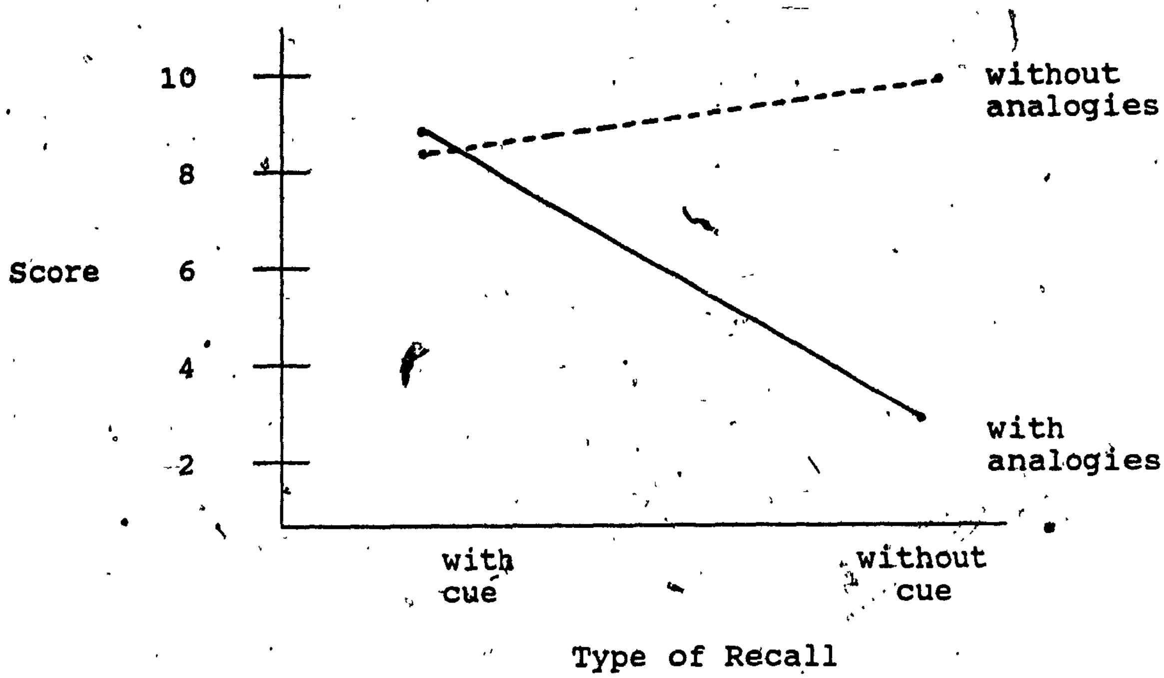

Table 2

Means and Standard Deviations of Questions Which Dealt with Analogies

	With Cue		Without Cue	
	M	SD	M	SD
With Analogies (a)	8.44	3.57	3.67	2.83
Without Analogies (b)	8.25	4.37	10.00	4.98

(a) n = 9 for each group
(b) n = 8 for each group

without analogies ($M = 34\%$), $t(7) = 2.66$, $p < .05$. Normally, significant differences found in the control group indicate a testing bias and would suggest that the questions which deal with analogies were easier to answer either because the subjects had relevant prior knowledge or because the content for those particular questions was less difficult for the subjects. In this case, however, the performance of the experimental group was opposite to that of the control group, indicating that the analogy interfered with the performance of the subjects in the experimental treatment.

When the scores for questions which do not deal with analogies were considered, there were no significant differences between the treatment groups (see Table 3). The detrimental effect on performance found with the use of analogy was therefore restricted to only those questions which refer to analogies and did not affect other responses.

<u>The Effect of the Elaboration of the Analogy</u>

In order to determine whether the elaboration of the analogy is a significant factor in the performance of the subjects who received the analogy, an analysis of variance with type of recall and the use of elaboration was performed using percentage scores. A marginally significant main effect for elaboration was indicated $F(1,16)$ $p = .06$ (see Table 4). Mean percentage scores indicate that analogies which were elaborated (Marginal Mean = 36%) resulted in

Table 3

Means and Standard Deviations of Questions Which Did Not Deal With Analogies

	With Cue		Without Cue	
	M	SD	M	SD
With Analogies (a)	3.89	2.15	3.11	2.76
Without Analogies (b)	5.63	1.68	3.75	2.6

(a) n = 9 for each group
(b) n = 8 for each group

Table 4

Percentage Scores and Standard Deviations of Elaborated Versus Non-Elaborated Questions

	With Cue		Without Cue	
	M	SD	M	SD
With Elaboration	48.15	17.56	24.07	20.60
Without Elaboration	33.33	34.23	9.72	12.14

n = 9

higher performance than analogies which were not elaborated (Marginal Mean = 21%). (Elaborated analogies explain the concept in both the topic and analogic situation; non-elaborated analogies are in the form of a simile.) This result suggests that the detrimental effect of the analogy is not a result of the elaboration of the analogy.

In order to ascertain the general effect of elaboration, an analysis was completed of the control group's performance on elaborated versus non-elaborated items. (Recall that elaboration in the topic situation remained even though the analogy was absent.) A correlated t-test performed on the mean percentage score of responses in the control group indicated that elaborated items (*M* = 60%) resulted in significantly higher performance than non-elaborated items (*M* = 34%), $t(7) = 2.49$, $p<.05$. Since the presence of elaboration enhanced performance, regardless of whether the analogy was present or not, it is not possible to make any definitive statement regarding the effect of elaboration with the analogy.

<u>The Control Test</u>

A control test was given to subjects in the With Analogy, No Cue condition to verify if subjects in this group could recall the analogy when answering the questions on the post-test. Subjects were asked to identify the analogy which was in the text upon presentation of the topic. As expected, none of the subjects was able to recall the analogies on the control test. Any difference in results on the post-test between the With Analogy, With Cue group and the With Analogy group is assumed to be a result of the presentation of the prompt.

Attitudinal Data

In order to understand what subjects thought about the use of analogies to clarify information in the experimental material, attitudinal data were collected with Lickert type scales. On a five point scale, subjects found the material to be average in terms of the level of difficulty of the material and their interest in the material. The analogies in the text were rated as "useful" for the With Analogy, With Cue condition and "average" for the With Analogy, Without Cue condition. The presentation of the cue on the post-test improved both the performance of those subjects who received the cue as well as their attitude towards the analogy. Overall, however, the subjects were not overwhelmed by the use of the analogy in the experimental text as a means of clarifying the information which was presented to them.

CHAPTER FIVE

Discussion

The purpose of this study was to isolate cognitive variables involved in learning with analogy with the intention of identifying specific learning outcomes. Three variables were manipulated: the use of embedded analogies, type of recall, and the use of elaboration with respect to the analogy. While prior research has generally found that analogies facilitate the acquisition of information, the presentation of a cue at the recall stage was used to determine whether analogies also facilitate the retrieval of information. The effect of elaboration of the analogy was included as a possible confounding factor; prior research has indicated conflicting results with regard to the use of author provided elaborations and since an analogy is a type of elaboration, its effect with the analogy was also investigated.

The overall effect of the analogy, contrary to what was expected, was to hinder learning performance. Subjects who received the analogy with the cue performed as well as the control group, and subjects who received only the analogy performed significantly worse than both the control group and the cued analogy group. Since facilitative effects of learning with analogy at the acquisition phase were not found, this confounded the results of the study so that the use of analogies at the acquisition phase could not be compared with retrieval effects as originally planned in this investigation. Rather, reasons for the decrement in the performance of subjects as a result of using analogies are examined.

One reason the subjects did not perform well when provided with analogies is that an interaction was present between the content and the teaching strategy. Since subjects in the control group performed significantly better on questions which dealt with analogies than questions which did not deal with analogies, it appears that these concepts were, by nature, easier for the subjects to assimilate. These concepts, however, were also chosen by the experimenter as lending themselves to elaboration by analogy and were chosen as concepts for which analogies would be presented. It seems that content difficulty and analogical tendency are inversely related, and resulted in this study in an experimental artifact which was in direct opposition to enhancement strategies.

According to research, analogies should be provided when the material is difficult and the learner does not have prior knowledge of the material (Royer and Cable, 1975). When subjects are already familiar with the material, the effect of the analogy can be to overload the learner with unnecessary information (Zeitoun, 1981). In this study, every effort was made to include information which the subjects were not familiar with, and indeed, the overall performance score indicates subjects found the material difficult. Nevertheless, based on the performance of the control group, the relative knowledge subjects had for some of the content area interfered with the instructional strategy, thereby confounding any positive effect which could result from the analogies. It is possible that the analogies provided the subjects with unnecessary and/or conflicting elaborative information which was a burden and distracted the learner from the topic to be learned.

While the presence of the analogies at the acquisition phase hindered learning performance, subjects who received the analogy with the cue performed significantly better than subjects who only received the analogy. According to Stein et al. (1984), elaborative information, in this case analogies, facilitates the retrieval of target information only when the information is well integrated during the encoding phase. Fisher and Craik (1980) furthermore indicate that if the elaboration is not well integrated, then the encoding context must be reinstated at the time of retrieval in order for benefits to result from the elaboration. In this study, subjects were able to retrieve the target information when presented with the prompt, suggesting that the analogies (both elaborated and non-elaborated) were not well integrated during the acquisition phase.

It is possible that the subjects failed to integrate the analogies into their existing schemata because they were not necessary for learning to occur. Since none of the experimental treatments performed better than the control group, it is also possible that the subjects either failed to understand the analogy, or failed to recognize the isomorphic relationship between the analogy and the target content . As Sticht (1979) points out, some learners may not have the required experiences to receive the large chunks of information which are transferred by the analogy.

In summary, the presence of the analogies hindered subjects' performance. This was likely due to an interaction between the instructional strategy and the learner. Concepts which subjects in the control group found easier to deal with were inadvertently chosen by the experimenter as concepts to elaborate upon in the experimental treatment, thereby providing subjects with elaboration when none was either required or useful. Since the cue facilitated the retrieval of information, this suggests that the analogy was not well integrated with the target information during the acquisition phase.

With respect to the additional elaboration of the analogy, a definitive conclusion cannot be reached. The presence of elaboration enhanced performance in the control group when no analogy was present and marginally enhanced performance in the experimental group in the presence of the analogy. Overall, it seems that the effect of elaboration did not interact with the overall detrimental effect of the analogy.

Instructional Implications

The results of this study emphasize the need to carefully select content when using analogies as an instructional strategy. It is possible that topics which most easily lend themselves to analogies, and which are most often selected as targets for analogies, are concepts which the learner will also find easy to elaborate upon and to produce their own analogies. In terms of the acquisition of information, the implication of this study is that analogies are more appropriate for remedial work. If it has been determined that the learner is not able to assimilate the material via his/her own learning strategies, then author-provided analogies are recommended in the form of remediation.

Based on these results it seems that less instruction is better for concepts which students have a predisposition towards assimilating using their own learning devices. In a similar vein, McDaniel and Kearny (1984) found that college students were able to spontaneously utilize effective semantic and imaginal strategies without instruction to do so, and performed as well as subjects who were instructed to employ the most effective learning strategy for a particular task. In the study reported here, subjects were better able to utilize an effective learning strategy for those concepts which were elaborated upon by the author. The implication for the design of instructional materials, therefore, is that the instructional designer should consider the effect of author-provided strategies on learner generated strategies and be aware that in the presence of both types of strategies, learning performance may deteriorate.

In terms of the retrieval of information, analogies were found to temporarily facilitate the reconstruction of target information. While previous research has failed to support the activation of specific knowledge with analogies, this study found that analogies resulted in the activation of specific knowledge, but only in the presence of a prompt during the recall phase.

It is interesting to note that on the post-test some students in cued analogy group recalled the analogy rather than the target information. Either the subjects did not think it was necessary to recall the target information, or they were not able to remember the relationship between the analogy and the target. It is possible that the process of retrieving information with the aid of a prompt entails a complex procedure whereby learners have to first remember the analogy and then reconstruct its relationship to the target information. Under such conditions, the use of analogy as a recall device is not an efficient means of retrieval. While the prompt served to elicit specific information, the retrieval benefits of analogies do not promote long-term effects or higher-order learning outcomes according to the results of this study.

Recommendations for Future Study

The present study could be reconducted with materials which contain effective analogies. Once the effectiveness of the analogies has been established, the experimenter could then determine the locus of effect as was initially planned in this study.

The use of an instructional strategy was an impediment to learning and should also be investigated. Previous research has found that learner-generated elaborations tend to be more effective than author-provided elaborations. In order to determine whether the author-provided elaborations caused the decriment in learning in this study, a further study could investigate the effect of learner-generated elaborations as an experimental treatment. If the group with learner-generated elaborations performs better than the group receiving author-provided elaborations, the decriment in performance is a result of conflicting elaborative information provided by the author. If, on the other hand, learner-generated elaborations are found to be less effective than author-provided elaborations, this would suggest the learners were less able to generate, understand and/or assimilate their own analogies.

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APPENDIX I

You are probably already familiar with what a program does, that is, a program is a set of instructions which tell the computer what to do. What you may be less familiar with is what happens after you give the computer a set of instructions. This hand-out will deal with the events which surround the processing of a set of instructions which you, the user, have given to the computer.

Programming languages such as BASIC, PASCAL and FORTRAN were created by programmers in order to make communicating with the computer an easier task. Rather than program in **machine language**, which is the language the computer understands, we can write a series of instructions for the computer in a language which more closely resembles English.

A programming language is furthermore easier to use because it may summarize several instructions to the computer in a single program command. For example, when you ask the computer to multiply 12 by 24, you are asking to have a whole series of additions and multiplications performed. A single program command, however, is sufficient to put into effect the operations which are required to do a multiplication. This is similar to the language used in cooking. For example, in cookbooks you often see the verb "sauté". You know that sauté means "take out a frying pan, melt butter, and cook the ingredient lightly in it". All of these instructions are conveyed in a single word. Just as you translate the word "sauté" into its elementary steps when you cook, the computer translates a program command into its elemental instructions before the operation is carried out.

Before the computer can understand a programming language such as BASIC, COBOL or FORTRAN, or even a data base programming language, the commands have to be translated into the 1's and 0's of machine language. To understand the conversion process, imagine that you were asked to give a speech to a group of Chinese dignitaries at a convention and that you had to do it in Chinese since no one in the group spoke any English. There are two possible ways to deal with this problem, just as there are two possible ways of converting your program into machine language. One way is to have a translator by your side at the convention. Every sentence you said in English could then be translated, on the fly, into Chinese by your translator. Since your translator would be right beside you, you could give your speech and improvise as much as you wanted. The other possibility is to go to a translator and have her translate your speech into a cassette recorder beforehand. Then you could go to the conference with your speech prerecorded in Chinese and just play the tape. In this scenario, however, you would only be able to play the tape of your speech; for example, you couldn't alter your speech or make any further comments.

Similarly, a computer only understands machine language

(Chinese) while your program (speech) is written in a programming language. One possibilty is to have each instruction in your program simultaneously translated into machine language when the program is being executed. This is akin to you having a translator by your side while you were giving your speech. Programs which are converted into machine language line by line as the program is being executed are said to be **interpreted**. Interpreted programs can only be used if the interpreter (translator) is accessible as well since it is the interpreter which does the conversion into machine language. The other type of program conversion is done in advance by the program developer before the software is sold to the consumer. Programs such as these are said to have been **compiled** and are permanently converted into the machine language that the computer needs to run the program. This is like you having your speech translated and recorded on tape before the conference.

There are drawbacks associated with both approaches. Once a program has been compiled, you cannot change any of the instructions in the program, just as you would not be able to alter your speech once it had been recorded. In contrast, programs which have been interpreted can be modified by a programmer since the interpreter (translator) is always there to make the required conversion into machine language. However, it takes longer for the computer to process an interpreted program because each line of instruction must be converted into machine language by the interpreter (translator).

Bear in mind that all the instructions of a program actually get processed in the **Central Processing Unit (CPU)** which is the 'brain' of the computer. However, the instructions which the CPU is to follow are stored not in the CPU but in the memory of the computer which is located outside the CPU. The memory is where the CPU finds its program and data when it is doing its assigned task. The CPU uses its memory as a workspace just as an office worker uses a desktop or a carpenter uses a workbench. Memory merely provides the computer with a place to store the program which is currently being executed just as a desktop provides a place to hold papers which are currently being worked on.

Since the instructions which the CPU is to follow are held in memory, there needs to be some way for the CPU to locate and access that information. The mechanism for accomplishing this is 'random access'. The easiest way to understand random access is to think of a bunch of pigeon-hole-type mailboxes of the kind you see in hotels where each mailbox has a number. When a guest asks for the key to her room the hotel clerk doesn't look at each mailbox, starting with the first box then checking the second box, and so on, until he finds the right one. Rather, the clerk will go directly to the box which was specified in order to get the key. Similarly, a program might refer to a particular address, as in "go to mailbox 835".

When a particular mailbox is referenced the CPU doesn't have to look at each mailbox in sequential order; instead, the CPU just looks in the mailbox specified. This way of accessing information is called random access, hence the term **Random Access Memory (RAM)**. The ability of the CPU to jump to a particular address in RAM makes everything go much faster when it is following instructions in a program.

There is another kind of memory where instructions are permanently stored. This memory is called **Read Only Memory (ROM)**. The programs which are built into ROM perform fundamental supervisory and support tasks and cannot be altered by the user. These programs are called the Basic Input/Output services or BIOS for short. You often hear them referred to as the ROM-BIOS since they reside in Read-Only-Memory. The ROM-BIOS programs provide basic instructions to the computer on how to manipulate its hardware. For example, instructions concerning how to send characters to the screen, how to write characters on a disk or how to read incoming characters from the keyboard are stored in ROM.

Since the CPU does the actual processing of information it needs to communicate with the rest of the computer system. Getting the rest of the system to work with the CPU requires many detailed instructions. For instance, look at the steps necessary for printing. Before beginning to send characters to the printer, a program must verify that the printer is turned on and ready to receive information. If the printer is ready, it responds with a signal within a certain time period. If this doesn't happen, an error message must be sent to the screen to tell the user she forgot to turn on the printer. A similar process must occur in order to verify that the paper isn't jammed, the ribbon isn't used up and so on. A whole other set of instructions, that is, a different protocol, is also required for other peripherals such as the disk drive and the screen. As you can well imagine there is a constant flow of communication between all the different components of the computer and the CPU. The Operating System has the job of regulating this flow of various signals going to and from the CPU and its peripherals. The operating system is like the traffic cop who gives instructions to motorists. These instructions are necessary to make sure there isn't a traffic jam when two peripherals try to communicate with the CPU simultaneously.

In order to further understand how the CPU communicates with the rest of the system, we first have to know something about how information in the computer is represented. The main unit of data is the byte. The byte is the building block for both numbers and text data. Each byte represents one character of information, where a character can be a number, a letter, or a special character (such as a punctuation mark or a parenthesis). Each byte is made up of 8 bits. Realistically speaking, the computer doesn't understand bits or bytes but only electrical impulses. A bit is really either the presence or absence of an electrical impulse. There are only two different bit values, zero (0), which means nothing or no electrical signal and one (1) which means one electrical signal. Because it's possible to make electronic machines that work with on/off signals at great speed, we can make machines that work with real information. This all depends, however, on our ability to match information that is meaningful to us with information the computer can work with, namely, the presence or absence of electrical impulses.

In order to communicate with the rest of the computer system, the CPU sends electrical signals along wires which are collectively referred to as the Bus. Parts of the computer system must be connected to the bus in order to receive those signals and possibly to respond with signals of their own. Any part of the computer that the CPU needs to talk to is given a number, called a port number, by the designers of the computer. The CPU uses that number, similar to a telephone number, to call up the particular part. For example, one port number is used to communicate with the keyboard, another number is used to give instructions to the disk drive and another is used to transfer data from RAM to the CPU. It is the designers of the computer who decide which port numbers to use for various purposes, and which elements of the computer should be wired up to respond to those numbers. When the CPU needs to talk to one circuit part or another it signals the port number and the appropriate part responds on the bus.

Buses come in various sizes. If 8 bits can be sent simultaneously then we have an 8 bit bus. One of the reasons for the greater speed of some computers is that they have a 16 bit bus, which enables them to move 16 bits at a time, therefore doubling the efficiency by which messages are sent.

As previously mentioned, RAM is the place where the CPU finds its program instructions and also its data. Random-Acess-Memory is located outside the CPU. In order to carry out its work, the CPU needs to have available a memory which is internal or, if you like, inside the 'brain'. **Registers** provide such a mechanism in the form of a small, special-purpose kind of memory located in the CPU. Registers are similar to the computer's main memory in one way: they are a set of places where data can be stored while the CPU is working with them. On the other hand, while the computer's main memory is large, the registers, on the other hand, are a series of small memory spaces. (The IBM AT, for example, contains fourteen 16 bit registers.) Registers temporarily store information while it is being processed in the CPU. In effect, each register is like a small scratch pad that the CPU uses for calculations and record-keeping. A great deal of the work that goes on inside our computers takes place in these registers.

APPENDIX II

You are probably already familiar with what a program does, that is, a program is a set of instructions which tell the computer what to do. What you may be less familiar with is what happens after you give the computer a set of instructions. This hand-out will deal with the events which surround the processing of a set of instructions which you, the user, have given to the computer.

Programming languages such as BASIC, PASCAL and FORTRAN were created by programmers in order to make communicating with the computer an easier task. Rather than program in **machine language**, which is the language the computer understands, we can write a series of instructions for the computer in a language which more closely resembles English.

A programming language is furthermore easier to use because it may summarize several instructions to the computer in a single program command. For example, when you ask the computer to multiply 12 by 24, you are asking to have a whole series of additions and multiplications performed. A single program command, however, is sufficient to put into effect the operations which are required to do a multiplication. The computer then translates the program command "to multiply" into its elemental instructions before the operation is carried out.

Before the computer can understand a programming language such as BASIC, COBOL or FORTRAN, or even a data base programming language, the commands have to be translated into the 1's and 0's of machine language. There are two possible ways to deal with this problem. One way is to have each instruction in your program simultaneously translated into machine language when the program is being executed. Programs which are converted into machine language line by line as the program is being executed are said to be **interpreted**. Interpreted programs can only be used if the interpreter is accesssible as well since it is the interpreter which does the conversion into machine language. The other type of program conversion is done in advance by the program developer before the software is sold to the consumer. Programs such as these are said to have been **compiled** and are permanently converted into the machine language that the computer needs to run the program.

There are drawbacks associated with both approaches. Once a program has been compiled you cannot change any of the instructions in the program. In contrast, programs which have been interpreted can be modified by a programmer since the interpreter is always there to make the required conversion into machine language. However, it takes longer for the computer to process an interpreted program because each line of instruction must be converted into machine language by the interpreter.

Bear in mind that all the instructions of a program actually get processed in the **Central Processing Unit (CPU)**.

However, the instructions which the CPU is to follow are stored not in the CPU but in the memory of the computer which is located outside the CPU. The memory is where the CPU finds its program and data when it is doing its assigned task. The CPU uses its memory as a workspace: memory merely provides the computer with a place to store the program which is currently being executed.

Since the instructions which the CPU is to follow are held in memory, there needs to be some way for the CPU to locate and access that information. The mechanism for accomplishing this is 'random access'. For example, a program might refer to a particular address in memory, as in "go to address 835". When a particular address is referenced, the CPU doesn't have to look through every address in memory from 1 to 835 in sequential order; instead, the CPU just looks directly at the adress specified, namely, 835. This way of accessing information is called random access, hence the term **Random Access Memory (RAM)**. The ability of the CPU to jump to a particular address in RAM makes everything go much faster it is following the instructions in a program.

There is another kind of memory where instructions are permanently stored. This memory is called **Read Only Memory (ROM)**. The programs which are built into ROM perform fundamental supervisory and support tasks and cannot be altered by the user. These programs are called the Basic

Input/Output services or BIOS for short. You often hear them referred to as the ROM-BIOS since they reside in Read-Only-Memory. The ROM-BIOS programs provide basic instructions to the computer on how to manipulate its hardware. For example, instructions concerning how to send characters to the screen, how to write characters on a disk or how to read incoming characters from the keyboard are stored in ROM.

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PLEASE RECORD THE TIME WHEN YOU ARE FINISHED READING THE ABOVE TEXT AND BEFORE YOU GO ON TO THE NEXT SECTION (e.g, Write 3 hours 45 minutes if it is 3:45 PM)

TIME: ___ hours ___ minutes

APPENDIX III

Instructions: Please answer the questions below as well as you can. If you need additional space, continue on the back of the paper. You have as much time as you need to complete this.

1) Give two reasons why a programming language facilitates giving instructions to the computer.

It may be helpful to recall that in the text a comparison was made between the language used in cooking and programming languages.

---

2) a) Explain two different ways in which a program can be converted into machine language (i.e, explain interpretation and compilation)

You may recall that in the text two different ways to translate a speech into Chinese were described.

---

b) Name a disadvantage for each way.

---

3) What function mentioned in the text does the Operating System have?
In the text the operating system was compared to a traffic cop.

---

4) Describe how the computer locates information in RAM.
In the text the computer was compared to a hotel clerk.

---

5) Compare and contrast RAM with registers. (Give three points.)
It is helpful to remember that RAM was compared to a desktop in the text and a register was compared to a scratchpad.

---

6) a) Can instructions which are stored in the ROM-BIOS be altered by the user?
Yes / No

b) What kind of instructions are stored in the ROM-BIOS? (Give one example)

---

7) What purpose does the port number serve?
In the text the port number was compared to a telephone number.

---

8) In terms of hardware mentioned in the text, how can the processing speed of a computer be increased?

---

9) What is a basic limitation in terms of how we, as humans, can communicate with the computer?

THIS COMPLETES THE QUIZZ. PLEASE ANSWER THE QUESTIONS ON THE FOLLOWING PAGE BEFORE HANDING IN YOUR MATERIALS.

<u>Note</u>. Questions 1) 2a) 2b) and 4) refer to elaborated analogies. Questions 3) 5) and 7) refer to non-elaborated analogies.

1) Do you have a computer at home? Yes / No

2) How many computer courses and/or courses related to the content of the text have you taken? (Do not include the Records Management course you are currently enrolled in or any Word Processing course.) __________

3) How familiar were you with the information which was presented in the text?

very familiar	familiar	not very familiar	not at all familiar
1	2	3	4

4) How difficult did you find the information in the text?

very easy	easy	average	difficult	very difficult
1	2	3	4	5

5) How interesting was the information?

very interesting	interesting	average	not very interesting	tedious
1	2	3	4	5

6) Were the analogies presented in the text helpful in terms of clarifying information which was presented in the text?

very helpful	helpful	average	not very helpful	not at all helpful
1	2	3	4	5

7) Were the analogies which were repeated on the quizz useful in terms of recalling the information presented in the text?

very useful	useful	average	not very useful	not at all useful
1	2	3	4	5

Thank you very much for your cooperation.

APPENDIX IV

Instructions: Please answer the questions below as well as you can. If you need additional space, continue on the back of the paper. You have as much time as you need to complete this.

1) Give two reasons why a programming language facilitates giving instructions to the computer.

---

2) a) Explain two different ways in which a program can be converted into machine language (i.e, explain interpretation and compilation).

---

b) Name a disadvantage for each way.

---

3) What function mentioned in the text does the Operating System have?

---

4) Describe how the computer locates information in RAM.

---

5) Compare and contrast RAM with registers. (Give three points.)

---

6) a) Can instructions which are stored in the ROM-BIOS be altered by the user?

Yes / NO

b) What kind of instructions are stored in the ROM-BIOS? (Give one example)

---

7) What purpose does the port number serve?

---

8) In terms of hardware mentioned in the text, how can the processing speed of a computer be increased?

----

9) What is a basic limitation in terms of how we, as humans, can communicate with the computer?

APPENDIX V

In the text analogies were used to explain some of the concepts presented in the text. In the space provided please indicate, if possible, the analogy which was presented in the text for each of the following concepts. An example is given.

0) Concept: CPU

Analogy: The CPU is the brain of the computer.

1) Concept: A programming language

Analogy: ______________________________

2) Concept: The Operating System

Analogy: ______________________________

3) Concept: The memory of the computer (RAM)

Analogy: ______________________________

4) Concept: Registers

Analogy: ______________________________

5) Concept: Port numbers

Analogy: ______________________________

6) Concept: The process of converting a program into machine language (i.e, interpretation and compilation).

Analogy: ______________________________

7) Concept: The process whereby the computer locates information in RAM

Analogy: ______________________________

APPENDIX VI

Scoring Criteria

QUESTION # 1

a) (A programming language) summarizes
   commands/instructions.
   Saves time (in programming).

b) (A programming language) resembles English.
   (It is) easier to use/to understand.
   (You) don't need to use machine language.

QUESTION # 2A

a) (Compilation) is done beforehand/ it is done by a
   programmer.
   The whole thing is translated/ recorded.

b) (Interpretation) is done simultaneously/line by line/step
   by step/on line.
   Information is entered then translated.

QUESTION # 2B

a) Translator (interpreter) must be accessible.
   It takes longer (to process).

b) You cannot change/add anything (in the program).

QUESTION # 3

It regulates the signals among the peripherals/going to the CPU.
It directs the traffic of signals/impulses/commands.

(1 point) Prepares printer.

QUESTION # 4

Direct access.
Goes to the address.
Goes straight/exactly to the information.

QUESTION # 5

a) Small versus large memory/storage area.
b) Both RAM and registers) store information/are part of memory.
Information is temporary.

Information can be manipulated.
RAM stores the program, registers don't.

c) (Registers are) inside versus (RAM which is) outside the CPU.

QUESTION # 6

a) No
b) Basic input-output (instructions).
Instructions already in the computer.
Printer/hardware instructions.
Checks the printer.
(How to) read the disk.

(1 point) How to operate the computer.
Instructions to the computer.
Input-Output instructions.

QUESTION # 7

To call up a particular part.
To identify part(s) of the computer.
To transfer an instruction to the proper peripheral.

(1 point) To locate, to identify. (To locate something other than a part is = 0 points.)

QUESTION # 8

Larger bus/16 bit bus.
Increase the efficiency of sending messages.
Add a compiler.

(1 point) More bits/bytes.

QUESTION # 9

Our inability to represent information in a manner the computer will understand.
(The use of) machine language/computer language.
Computers don't know English.

(1 point) We don't know computer language.