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Instructing With Analogies

P. R. J. Simons
Tilburg University, The Netherlands

Three functions (a concretizing function, a structurizing function, and an active assimilation function) that might explain why analogies are effective reading aids are discussed. Six experiments are reported that attempt to answer the following questions: (a) Does the addition of concrete analogies lead to improved performance in subjects of different ages? (b) Does this lead to longer reading times? (c) What are the effects under restrictive time conditions? (d) Are there aptitude-by-treatment interactions? (e) Why are analogies effective reading aids? These experiments used subjects from elementary and secondary schools, and college students studying science, biology, developmental psychology, and computer programming. The results generally showed that analogies are effective reading aids; however, there are doubts as to their efficiency because they are effective only when there is enough time available. Yet some findings indicate that performance gains outweigh time costs. Some support was found for all three of the previously mentioned functions.

"We reason analogically whenever we make a decision about something new in our experience by drawing a parallel to something old. When we buy a new goldfish because we liked our old one, or when we listen to a friend's advice because it was correct once before, we are reasoning analogically" (Sternberg, 1977, p. 353). Likewise, one reasons analogically when one tries to understand or learn new concepts or phenomena by drawing a parallel to old familiar concepts or phenomena (see Pask, 1976). Instructing with analogies refers to the presentation of analogical information that can be used in the form of analogical reasoning in learning.

Whenever something is explained using comparisons with other phenomena or concepts, this is called *instructing with analogies*. For instance, the structure of a computer may be described by comparing it with a post office counter that is connected to a shopping list that is connected to a typewriter (Mayer, 1975). Likewise, the actions of electrons in wires can be described by comparing them with human beings while dancing (Bell & Gagné, 1979).

Several theoretical arguments have been raised for the usefulness of instruction with analogies. For instance, Ortony (1975) argued that some things may be expressed more vividly and richly using analogies. Davidson (1976) also stressed the vividness of concrete analogies. According to Davidson, analogies are effective learning aids because they make abstract information more imaginable and concrete. This is called the *concretizing function*.

Two other important theoretical functions have been emphasized. Rumelhart and Ortony (1977) and Norman (1978) argued that in creating a new schema, an existent analogical schema may be used as a formal structure that can form the basis for the new schema. In this way the formal structure of the new schema does not need to be learned. All one needs to do is supplement this formal structure with new information. In these conceptions analogies function mainly to *structurize* new information.

The third theoretical function of analogies—*active assimilation*—results from two recent miniature theories (Mayer, 1979a, 1979b; Wittrock, 1979). According to Mayer's assimilation theory, the presentation of analogies may, at least under some conditions, make relevant anchoring ideas available and stimulate students to integrate actively the new information and previously learned information in the cognitive structure. According to Wittrock's generative

Requests for reprints should be sent to P. R. J. Simons, Department of Instructional Psychology, Tilburg University, Post Box 90153, 5000 LE Tilburg, The Netherlands.

learning model, learning involves the active construction of meaning for stimuli using all kinds of processing. Learning with understanding is the process of transferring previous experience to new events and problems. Instruction should, according to Wittrock, be designed so that active construction of meaning by students is stimulated as much as possible. The presentation of analogies may often stimulate students to process learning materials more actively.

Apart from the positive aspects of these three functions, several drawbacks should be noted (see Davidson, 1976; Miller, 1976; Simons, 1982). One of the most important possible drawbacks of analogies in instruction may be the extra reading time they may require (see Simons, 1983).

The effects of learning with and without analogies have been evaluated in several studies under different labels (e.g., concrete models, analogies, concrete advance organizers; Mayer & Bromage, 1980). Many investigators found significant differences between learning with and learning without (concrete) analogies (Lesh, cited in Mayer, 1979b; Mayer, 1975, 1976, 1978, 1979a, 1979b; Rigney & Lutz, 1976; Royer & Cable, 1975, 1976; Scandura & Wells, 1967). Some found these effects for far-transfer tests only, and not for near-transfer tests (Mayer, 1976). Mayer and Bromage (1980) showed that learning with concrete models resulted in better general ideas and more inferences and intrusions than learning without them. However, subjects learning without the models retained technical information better. It seems clear that analogies may be effective learning aids, at least with the kinds of materials and subjects used in the experiments mentioned. Unfortunately, research thus far has been limited to certain kinds of subjects (college students) and materials (short texts). Furthermore, although there is some indication that instructing by analogy is effective, it is not really known why.

Finally, in past research on analogies, no attention has been given to reading time and efficiency. As I have argued (Simons, 1981, 1983), this is a serious omission. Not only can analogies directly influence reading time because of the extra words involved (Faw & Waller, 1976), but two indirect influences can also have some effect. The first indirect influence is an *indirect lengthening of study time*. Analogies may cause subjects to study a text longer (apart from the direct effect). Because analogies stimulate a different kind of processing in the learner (i.e., more actively or more deeply in a comparative way), the text is processed slower than is a text without analogies. The second indirect effect is an *indirect shortening of reading time*. Analogies may also facilitate the reading of the text, causing an increase in the reading speed. Because of the analogy, a subject might understand a text sooner than if there was no analogy; thus, the subject may be able to read the text more quickly and easily.

The experiments that are reported in this article had three goals. The first was to evaluate the effectiveness of instruction with analogies in younger subjects studying longer texts than were used in most of the previous experiments. The second goal was to study the efficiency question and indirect time effects. The third was to clarify why analogies are effective reading aids. Regarding this last goal, the concretizing, structurizing, and active assimilation functions formed the major possible explanations. These were tested by comparing results of different kinds of dependent variables and by testing for aptitude-by-treatment interactions (ATIs; Cronbach & Snow, 1977). Individual differences in concretizing and structurizing abilities and styles were measured. It was expected that, if the effectiveness of analogies is due to one of the functions (e.g., concretizing), an ATI with the corresponding (concretizing) ability should appear. Because of space limitations, however, the ATI results are only briefly reported here.

In each of the experiments, analogies were constructed along the following guidelines. A to-be-learned text was analyzed in an intuitive way, answering questions such as: What are the main concepts in this text? What is the structure of the text? What are the relations among concepts? What major difficulties could arise for subjects who try to learn this text? Analogical concepts were then sought that (a) had the same formal relations as the to-be-learned concepts, but were more familiar, more concrete, or easier to learn, and (b) could expose the supposed difficulties. For instance, the following

passage, accompanied by drawings, was written as an analogy for a text on molecules, atoms, and substance.

When you break a biscuit in parts, you end with a crumble of the biscuit. This crumble still has the same properties as the biscuit. It has the same taste and ingredients (e.g., butter, sugar, spices) as the biscuit itself. One might say that the crumble is the smallest part of the biscuit still having the same properties as the biscuit itself. The crumble, however, can also be divided. Then you end with very little parts of sugar, butter, spice, and so on. These smaller parts have different properties than the biscuit.

Experiment 1: Unrestricted Time Conditions

Method

Subjects and design. Subjects were 61 pupils recruited from 6 classes of 4 secondary schools (MAVO[1]) in Tilburg, The Netherlands. The subjects ranged in age from 13 years to 15 years. A pretest–posttest control group design was used, with individual random assignment to the 2 conditions (with or without analogies).

Materials. The materials included a 14-page course on electricity (modified from Lodewijks, 1978), consisting of 3 parts. In the first part the concepts of substance, atom, molecule, and electron were treated. In the second part, potential, coulomb, volt, electrical current, and ampere were explained, and in the last part resistance and specific resistance were explained. In addition to concepts and their definitions and examples, relations among concepts, laws (e.g., Ohm's Law), and simple problems were discussed.

Five analogies were constructed and tested in pilot studies. The first one (175 words) dealt with the relations among a biscuit, a crumble of the biscuit, and ingredients of the biscuit (as compared with relations among substance, molecule, and atoms). The second analogy (200 words) involved a pair of scales (as compared to the balance between the charge of a nucleus and the number of electrons in an atom). The third analogy (380 words) described what happens when there is lack of food in a city and people leave for the country (compared with potential and electrical current). The fourth analogy (400 words) described some phenomena that occur to the flow of water when length and section of a waterhose vary (comparable with resistance and Ohm's Law). The last analogy (200 words) dealt with the amount of water that penetrates a raincoat depending on the material of the coat (to be compared with specific resistance).

A 40-item, multiple-choice test was constructed consisting of factual knowledge questions. Thirty of these items formed a pretest. Furthermore, a 20-item, multiple-choice comprehension test was constructed based on Anderson (1972).

Several short control tests were constructed to determine whether the experimental manipulations worked as intended. These control tests consisted of items dealing with the comprehension and retention of the analogies and with relations between the texts and the analogies. Finally, simple scales were constructed to measure the subject's opinions on the learning materials and the analogies.

Additional materials included a field independence test, an analogical reasoning test, and the Spy Ring History Test (Pask, 1976). This last test was designed to measure comprehension and operation learning styles. A comprehension learning style is one in which an overall picture of the subject matter is learned whereas an operation learning style is one in which rules, methods, and details are learned without an awareness of how or why they fit together.

Procedure. The experiment consisted of 4 sessions of 2 hr each. All sessions took place in groups of 10 to 20, in the pyschological laboratory of Tilburg University, Tilburg, The Netherlands. Subjects were paid for their cooperation. The first session was the same for all subjects and was devoted to the Spy Ring History Test. The second session (1 week later) started with the pretest. Experimental subjects were instructed on the learning and on the analogies and how to use them. Afterward, the experimental subjects received the first 2 analogies during 5 min. The control subjects completed a filler task. Following that, subjects were asked to study carefully the first part of the course on electricity once. When they finished, their reading times were recorded. Then the experimental subjects received the third analogy, and the control subjects again completed a filler task. After 5 min the second part of the course was distributed, and subjects studied this once and recorded their study times. After a break, the last analogies and the last part of the lessons were studied and reading times recorded. Then the comprehension test (for both groups) and the control tests (for experimental subjects only) were completed. Finally, the analogical reasoning test was administered.

In the third session (1 week later), the same procedure as in the second session was followed. All parts of the course were studied again by the experimental and the control groups. Experimental subjects also received the analogies again, and control subjects received new filler items. Also, the comprehension and control tests were completed anew, and the field independence test was administered. In the last session 2 weeks later, the retention test was completed as was the comprehension test, for the third time.

Data analysis. Data were analyzed via generalized regression analysis, using the hierarchical method of the Statistical Package for the Social Sciences (SPSS) Multiple Regression Program (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975). Effect coding was used according to the prescriptions of Kerlinger and Pedhazur (1973). Pretest scores were excluded from the regression analysis because they appeared to suffer from a floor effect. (Apparently, subjects had little

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[1] MAVO (Middelbaar, Algemeen Vormend and Onderwijs) schools are typical Dutch schools that prepare students for administrative occupations.

prior knowledge about the topic.) Treatment effects and ATIs were tested for in the analysis. A separate regression analysis was conducted for each aptitude (field independence, analogical reasoning, and operation learning style).

Results and Discussion

Means and standard deviations on six dependent variables for each of the treatment groups are given in Table 1. The percentages of variance explained by the treatment main effect and F ratios (based on 1 and 59 degrees of freedom) are reported. There was a significant difference on the comprehension test administered after the first reading ($p < .01$, one-tailed) and on the factual retention test administered 3 weeks after the learning took place ($p < .05$, one-tailed). Furthermore, there was a significant difference in reading time for the first reading ($p < .001$). On the other dependent variables, the observed differences were not significant. In the regression analyses with aptitudes entered first, treatment effects second, and interactions third, treatment effects were tested another time as in an analysis of covariance. The significant effects in the simple analyses remained so in these analyses. Now also the long-term comprehension difference was significant, $F(1, 57) = 3.45$, $p < .05$, one-tailed.

Only two of the tested ATIs were significant, and both involved operation learning as the aptitude: on the long-term tests, $F(1, 57) = 10.62$ for comprehension, and $F(1, 57) = 4.56$ for factual retention, both ps $< .05$. Subjects scoring high on operation learning performed better when they studied with analogies than without them. For subjects scoring low on operation learning, this difference was in the reverse direction for the comprehension test and nonexistent for the factual retention test.

Analogies in this experiment formed effective reading aids for children in secondary schools. Children studying with analogies performed better than did children studying without them on a comprehension test administered after one reading. They also performed better on a comprehension test and a factual retention test administered 3 weeks after the third reading. Apparently, analogies acted as encoding and retrieval aids (see Mayer, 1979a). The performance effects coincided with significant (indirect) time effects. The first reading in the experimental condition was significantly longer than in the control condition.

Although the results of this experiment indicate that analogies are effective reading aids, their efficiency is questionable. The performance effects were reached as a result of large time investments. Not only did the reading of the analogies take time (direct lengthening), but indirect time lengthening occurred (an average of 5 min for the first reading).

However, it cannot be concluded from these data that analogies are inefficient reading aids. First, it is not known whether the extra time if used differently would lead to higher results. An increase in learning

Table 1
Summary Data for Experiment 1

Dependent variables	Condition: With analogies *M*	With analogies *SD*	Without analogies *M*	Without analogies *SD*	Explained variance percentage	*F*
Comprehension test (after one reading)	7.9	3.3	6.2	2.0	10.0	6.79*
Comprehension test (after third reading)	8.4	2.5	7.3	3.0	3.7	2.28
Comprehension test (after 3 weeks)	6.8	2.7	5.7	2.3	4.3	2.65
Factual retention (after 3 weeks)	15.2	5.4	12.6	3.6	7.4	4.72**
Reading time (first reading)	25.3	3.8	19.9	3.5	36.0	33.06***
Reading time (second and third readings)	34.3	6.3	36.0	6.3	1.8	1.10

* $p < .01$, one-tailed
** $p < .05$, one-tailed
*** $p < .001$

performance does not appear to be a linear function of time. Second, analogies may increase the subjects' willingness to invest time that would not otherwise be used for study. Peeck (1977), for instance, found that control subjects did not use extra reading time at all.

In this experiment, clear performance differences were found in favor of learning with analogies, although during the control tests many subjects could not state which analogy concepts belonged to which text concepts. Obviously, differences might be greater when subjects are better able to see the right connections.

Experiment 2: Restricted Time Conditions

The second experiment used subjects and materials comparable with the first one; it could be considered a replication. In fact, this experiment was carried out at the same time as the first one. Main differences between the two experiments concern reading time control and aptitudes. In the first experiment, unrestricted time conditions combined with student-recorded times were used. In the second experiment, definite time limits were imposed. This experiment was directed at the question of efficiency, whereas the previous one was directed at effectiveness.

Method

Subjects and design. Subjects were 68 pupils from 3 MAVO schools in Tilburg. The ages of the subjects ranged from 13 years to 17 years; the average age was 13.6 years. A pretest–posttest control group design was used, with individual random assignment to the 2 conditions.

Materials. The same minicourse on electricity and analogies as in the first experiment were used, with one minor change. References to the analogies were inserted parenthetically. For instance, after the discussion on atoms and molecules, the following sentence was inserted: Compare atoms with ingredients of biscuits and molecules with crumbs.

The factual retention test from the first experiment was used in this experiment also. Fifty-seven items formed the long-term retention test. A sample of 30 items formed a pretest, and 15 of these, together with 15 others from the pool of 57, formed the immediate posttests that were administered directly after the learning took place. As in the previous experiment, several control tests were administered.

Visualizer–verbalizer dimensions were measured using a test procedure devised by Boekaerts (1979). This test uses an interference task based on experiments of Brooks (1968). This involves the measurement of the amount that someone coding verbal information is hindered by having to code visually at the same time and vice versa. The test is based on Brooks's (1968) results, which showed that verbal coding only interferes with verbal coding but not with visual coding and vice versa. Thus, someone who is hindered by a visual parallel task when coding verbal information is presumably using a visual channel in coding this verbal information (see Boekaerts, 1979).

Procedure. The experiment consisted of 4 sessions of 2 hr each. The first session for the experimental group started with extensive instruction (and examples) on learning with analogies. Thereafter, the pretest was administered to both groups. Then the actual learning took place. Experimental subjects studied the first 2 analogies and the first part of the minicourse during a maximum time of 50 min. (According to a pilot study, this amount of time was perfect for control subjects.) Control subjects also had 50 min, but they only had to study the text part. Subjects who had finished before the time was over recorded their study time. Finally, the immediate posttest was administered. (For the experimental subjects, the control test was given.)

The second and third sessions (1 and 2 weeks after the first session, respectively) were comparable with the first one. Again, a part of the minicourse was studied (with or without analogies), and an immediate posttest was administered. Maximum study times, however, were only 30 min in these sessions. (It was decided after the first session to reduce maximum study times because many subjects did not use all the time they were allowed.) In the final session (3 weeks after the third session), the long-term retention test was administered, and debriefing took place. One third of the subjects took part in the visualizer–verbalizer test procedure before and after each experimental session.

Data analysis. The decisions made concerning effect coding, significance testing, order of input in regression formulas, and so on were the same as in the first experiment. Pretest scores were again omitted because of the low-average scores.

Results and Discussion

There were no significant differences in performance on either the immediate posttest, means of 17.0 and 17.8 for experimental and control, respectively, $F < 1$, or the long-term retention test, means of 25.6 and 25.8 for experimentals and controls, respectively, $F < 1$. Although subjects were instructed to use all of the available study time, many decided to stop long before the end. Even during the first session, all subjects stopped before the time was finished. With the reduced nominal times of the second and third sessions, about half of the experimental subjects used all available time (63% and 53%, respectively), but almost

none of the control subjects in the second and third sessions did so (3% and 12%, respectively). This is remarkable in as much as these times were limited and results were far from good. The differences between study times in the two conditions are therefore underestimated (because half of the experimental subjects were forced to stop), but are still significant, Fs(1, 66) = 55.2, 63.6, and 31.5 for sessions 1, 2, and 3, respectively, all ps < .001. Mean reading times for sessions 1, 2, and 3 were 38.8, 28.1, and 28.2, respectively, for the experimental group and 26.5, 19.8, and 22.4, respectively, for the control group. With reference to the immediate recall test, significant interactions were evident on the visualizer–verbalizer dimensions. Verbalizers scored higher without analogies than with them, whereas visualizers performed better with them.

In this experiment, no significant differences appeared between the two conditions, whereas in the previous experiment they did appear. Because both experiments were performed with the same kinds of materials, subjects, and conditions, this is a remarkable difference. However, there are at least five possible ways in which the two experiments did differ. In Experiment 2 subjects' study time was restricted; massed practice was given (one text part per session); explicit reference was made in the text to the analogies that remained available during learning; no comprehension tests were administered; and a different aptitude test was administered.

The fourth and fifth differences are not serious candidates for the explanation sought, but the others are. The second difference (massed practice) can easily be eliminated. An explanation that analogies are only effective learning aids when distributed practice is used is counter to the significant difference in the previous experiment on the comprehension test administered after the first (massed) reading of the text. This explanation also clashes with the results of a subsequent experiment presented later. The third difference (explicit reference to analogies) forms a serious explanation: In this experiment, no significant differences were found as in the previous experiment because subjects did not actively compare analogies with the text. These comparisons were given in the text, and the analogies were constantly available. An interesting hypothesis is that analogies are effective reading aids when (and because) they stimulate learners to compare text and analogies actively (see Wittrock, 1979).

The last and, in this author's opinion, the best explanation concerns the first difference (study time control). According to this explanation, analogies are effective reading aids only when there is enough time for students to compare them with text concepts. In the second experiment, this time was not available because of the study time control. Half of the subjects in the experimental condition were forced by the experimenter to stop (at least during the last two parts of the course).

This experiment indicates that learning without analogies is as efficient as learning with them if one considers the finding that many experimental subjects used more of the available time. This conclusion is in itself correct, but it is only generalizable to the used nomial study times. When longer times are provided and subjects are prepared to use more time, results may be quite different (see Simons, 1983).

Experiment 3: Replication of Experiment 1

This experiment, which was comparable with the first one, aimed at investigating whether the results of the first experiment could be replicated in a more heterogeneous sample, with an improved version of the minicourse on electricity, other analogies, and more dependent variables. Special measures were taken to stimulate pupils to compare text concepts with analogies in order to attain higher scores on the control tests.

Method

Subjects and design. Subjects were 82 pupils from three schools in Tilburg (two MAVO schools and one HAVO/VWO[2] school). The subjects ranged in age from

[2] HAVO/VWO (Hoger Algemeen Vormend Onderwijs/Voorbereidend Wetenschappelijk Onderwijs) schools are typical Dutch schools that prepare students for higher education.

12 years to 16 years; the average age was 14.1 years. A pretest–posttest control group design was used, with individual random assignment to the 2 conditions.

Materials. The minicourse on electricity was used again but in a revised form. The course was simplified by shortening sentences, eliminating difficult words, changing the style, and omitting the most difficult parts of the course. The revision consisted of two parts of 7 and 9 pages, respectively.

The analogies were also adjusted. Eventually, three analogies remained. The first was the biscuit analogy used in the first experiment. The second analogy described what happens when a group of children enters a restaurant seeking an empty chair (to be compared with electrons, nucleus, charge, and free electrons). The third involved a school party where all boys get drinks for themselves and their girlfriends during a break. The speed of passage through the several corridors of the school depends on the speed of the barkeeper and the width of the corridors (to be compared with Ohm's Law).

To stimulate pupils to compare text concepts with analogies more efficiently, a two-page instruction was written on how they should be used. Also, questions were inserted in the text that explicitly asked pupils to compare text concepts with analogies. Control subjects answered neutral questions in the same places.

In addition to the factual knowledge test (60 items) and the comprehension tests (20 items), 2 new tests were constructed: a transfer test and a relation test. The transfer test consisted of 20 items in which the learned concepts and rules should be applied in new problem types not encountered before. The relation test (adapted from Lodewijks, 1978) consisted of 77 pairs of concepts from the minicourse. Subjects had to rate the relations between these pairs on a 5-point scale. Thirty-two of the pairs had no relation (NR) according to expert raters, and 26 pairs had an explicit relation (ER). Nineteen had a definite implicit relation (IR), that is, one that was not explicitly mentioned in the text. Following Lodewijks (1978), 2 scores were derived: reproduction and production. Reproduction scores denoted how well a learner reproduced the explicitly mentioned relations; production scores denoted how well a learner saw relations that were implicit in the text. Both reproduction and production scores were corrected for guessing in terms of the NR scores. The resulting formulas are: Reproduction = ER% − NR% and production = IR% − NR%.

As in Experiments 1 and 2, control tests and rating scales were constructed to measure whether pupils learned as expected. Also, the three tests (field independence, analogy, and the Spy Ring History Test) from the first experiment were used again.

Procedure. This experiment had the same four sessions as the first experiment, except for several changes. First, the pretest was administered in the first, instead of the second, session. Second, in session 2 the first part of the course was studied, and in session 3 the second part was studied. In the first experiment, all material was studied simultaneously (once in the second session and twice in the third one). Third, in the last session, the transfer test and the relation test were administered.

Data analysis. The procedures used were the same as in the first two experiments. Again, pretest scores were omitted from the regression analyses because of low means.

Results and Discussion

Means, standard deviations, percentages of explained variance, and F ratios for all dependent variables are given in Table 2. On the combined comprehension tests, no significant difference was observed between the conditions, $.05 < p < .10$, one-tailed. On the combined immediate recall tests (administered at the end of the second and third sessions), a significant difference was found,

Table 2
Summary Data for Experiment 3

	Condition					
	With analogies		Without analogies			
Dependent variable	*M*	*SD*	*M*	*SD*	Explained variance percentage	*F*
Comprehension tests	12.1	2.6	11.1	3.1	3.2	2.63
Immediate recall test	20.5	5.6	18.0	5.4	4.9	4.13**
Long-term retention test	29.1	10.3	26.4	10.3	1.7	1.40
Transfer test	9.3	3.7	7.9	3.6	3.6	2.99*
Relation test: reproduction	18.6	16.7	12.8	15.3	3.2	2.63
Relation test: production	11.8	17.0	2.4	14.8	8.1	7.05**
First reading time	40.1	8.4	37.3	7.1	3.1	2.53
Second reading time	18.1	5.5	22.3	4.9	14.4	13.51***
Total reading time	58.1	11.1	59.6	9.6	0.5	0.42

* $p < .05$, one-tailed
** $p < .01$, one-tailed
*** $p < .001$

$p < .01$. Also, the results on the transfer test and relation test (production scores) were statistically significant ps $< .05$ (one-tailed) and .01, respectively.

There were no significant differences on the long-term retention test (administered 2 weeks after the last learning session). The first reading of the text (thus excluding the time spent on the analogies) did not take more time in the experimental condition than in the control condition, $.05 < p < .10$, one-tailed. The second reading, however, took significantly more time in the control condition than in the experimental condition, $p < .001$. The total reading times for the two readings did not differ, $F < 1$.

No ATIs (defined by the variables field independence, analogical reasoning ability, pretest, age, comprehension learning style, operation learning style, and school type) were revealed.

Several results of Experiment 1 were replicated in this experiment. There were significant differences between the conditions on several dependent variables. There were also some differences and extensions. First, the time difference was less than in the first experiment and, more importantly, there was a significant difference in time in favor of the experimental group on the second reading. This means that an initial time investment in the first reading is regained in the second one, resulting in nearly equal total reading times. Second, in this experiment the difference on the long-term retention test (factual knowledge) was not significant. This agrees with Mayer's (1979a, 1979b) assimilation encoding theory which states that organizers influence the way information is integrated into long-term memory. Therefore, especially on certain dependent variables that are influenced by this integration process (e.g., a transfer test), differences may be expected. In contrast, such differences need not occur on other tests (knowledge tests; Mayer, 1979a, 1979b). Third in this experiment a significant difference appeared on the production relation test measure. From this result, it is clear that learning with analogies leads to a better view of relations between concepts, especially relations not mentioned in the text. This might be interpreted as support for the structurizing function.

Analogies formed more efficient reading aids in this experiment than in the two previous ones. Subjects spent extra time only on the reading of the analogies (direct effect), taking about 10 min per lesson. This relatively small investment of time led to significantly better results on achievement tests.

Unexpectedly, control tests (in which relations were given between analogies and text concepts) were also difficult for subjects in this experiment (subjects answered an average of 5 out of 9 items correctly). This is all the more remarkable because subjects had to answer the questions while learning the text with the analogies in view.

Experiment 4: Concrete Analogies Versus Comparative Organizers

The purpose of this experiment, together with the fifth and sixth experiments, was to compare results when using different kinds of analogies, and to see whether the results of the previous experiments might also be found in other samples with different subject matter and analogies. In the fourth experiment, analogies were compared with comparative organizers. Comparative organizers are, according to Ausubel (e.g., 1978), explicit comparisons between ideas to be learned and potentially confusing known ideas, formulated in an abstract and general way. Thus, comparative organizers are also analogies, but of a special kind. As in the analogies used in the previous experiments, comparative organizers contain known concepts and phenomena that are comparable with the to-be-learned concepts and phenomena. In comparative organizers, differences between this old, familiar information and the new information are made clear to prevent confusion that might arise when the organizer is absent. With the present concrete analogies, this confusion is not expected. Instead, analogical information that aims to facilitate comprehension and learning is presented. Although organizers in general have received much attention, comparative organizers were used in only four studies (Ausubel & Fitzgerald, 1961; Ausubel & Youssef, 1963; Fitzgerald & Ausubel, 1963; West & Fensham, 1976). This is a remarkably small number in that significant differences appeared in all four experiments favoring organizers over con-

trols. In expository organizer studies, the results were mixed (see Barnes & Clawson, 1975; Faw & Waller, 1976; Hartley & Davies, 1976; Lawton & Wanska, 1977; Mayer, 1979a, 1979b).

In this experiment, a special comparative organizer was used in one experimental condition. In this organizer, the meanings of new terms were compared with the more familiar, potentially confusing meanings. In the other experimental condition, concrete analogies were used, and in the control condition a neutral biographical introduction was used. It was hypothesized that abstract comparative organizers would lead to better results in verbalizers and concrete analogies would lead to better results in visualizers. In addition, it was expected that both kinds of analogies would lead to better results than the control introduction.

Method

Subjects and design. The subjects were 69 psychology students at Tilburg University fulfilling their obligation to participate in experiments. A pretest–posttest control group design was used, with individual random assignment to the 3 conditions (organizer, analogy, and control).

Materials. The subject matter in this experiment was an English developmental psychology text. Subjects studied pages 17 through 30 from *Piaget's Theory of Intelligence* (Brainerd, 1978), which covered Piaget's metatheory (assimilation, accommodation, equilibrium, organization, cognitive structure, and so on). Some parts were omitted from these pages (in particular, the analogies used and references to other chapters).

For the concrete analogy condition, three analogies were written. The first (one page) involved six changes on a football team when new players come into the team (comparable with qualitative vs. quantitative changes and structural vs. nonstructural changes). The second analogy condition (one-half page) treated equilibrium in a football team, and in the third (one-half page) cognitive structures were compared with architectonical structures and sentence structures. The first analogy was presented before the text was studied; the other two were woven into the text. Consequently, the study text of this condition was one page longer than that of the other conditions.

The material for the comparative organizer was one page long and consisted of explicit comparisons between ordinary language meanings and Piagetian meanings of the terms interaction, interactionism, and equilibrium. In the control condition a short (one- page) biographical introduction was studied, focusing on high points of Piaget's career.

Achievement was tested using a multiple-choice exam having 27 items and 2 open-ended questions. The multiple-choice test items were selected from a group of 50 items on the basis of a pilot study with 60 students. For each question subjects had to state whether they were certain or uncertain of the answer or had guessed. This test was used as a pretest, immediate posttest, and long-term retention test. For the 2 open-ended questions, 19 a priori scoring criteria were selected. Scoring took place following these criteria. As in previous experiments control tests and rating scales were constructed.

To measure the visualizer–verbalizer distinction, several different test procedures were used. First, the procedure devised by Boekaerts (1979) and described in a previous section was used. Second, a procedure devised by Richardson (1978) was used. The third measure was a paired-associated test devised by Levin, Rohwer, and Cleary (1971).

Furthermore, a specially designed questionnaire was administered, as was the Betts Questionnaire for Mental Imagery (QMI; Richardson, 1969). Finally, three Thurstone tests were used: Identical Forms, Concealed Figures, and Flags. These tests were used by many previous researchers (e.g., Richardson, 1978). Additional materials consisted of an achievement motivation test and a fear of failure test.

Procedure. The experiment consisted of three sessions. The first was a mass session in which all verbalizer–visualizer tests were administered to all subjects. The Boekaerts (1979) test procedure, however, was administered only to those subjects who had not participated in a previous experiment in which this procedure was used. During the second session (1 week later), the actual learning took place. Subjects were assigned to one of the three conditions at random, but the learning took place in the same classroom all together in groups of 20 to 25. First, the pretest was administered, and a written introduction was given to the subjects on how to study and use the introductory material. The subjects then studied the introductory materials for 10 min. Next, the lesson was studied for 50 min. This time limit was based on a pilot study with 8 subjects and was short enough so that no one had finished voluntarily; yet it was long enough so that everyone could read through all subject matter at least once (see Simons, 1983). After 50 min the immediate posttest and control tests were administered. During the third session (1 week later), the retention test and the open-ended questions were administered, and debriefing took place.

Data analysis. As in the previous experiments, generalized regression analyses were performed using the hierarchical method. Orthogonal coding was used instead of effect coding (see Kerlinger & Pedhazur, 1973) with corrections for unequal frequencies. Two vectors were created. In the first one the two experimental conditions and the control condition were contrasted; in the second one the contrast between the two experimental vectors was expressed. The pretest scores were excluded from the regression analyses because the mean was low.

Results and Discussion

Table 3 presents means and standard deviations on the three dependent variables. The only difference among conditions was an unexpected significant difference between the comparative organizer and the concrete

Table 3
Means and Standard Deviations for Each Condition (Experiment 4)

Condition	*N*	Immediate posttest		Retention test		Open-ended questions	
		M	*SD*	*M*	*SD*	*M*	*SD*
Comparative organizer	26	25.0	6.6	22.0	7.1	6.7	2.5
Analogies	22	23.4	5.2	17.9	6.0	5.9	3.3
Control	21	23.8	6.7	18.4	8.0	5.8	3.1

analogies on the retention test $F(1, 66) = 4.16$, $p < .05$. All other contrasts had associated ps $> .10$.

Some significant ATIs appeared. The contrast—concrete analogies and comparative organizer versus control—interacted with some of the visualizer–verbalizer dimensions (especially the test procedure of Richardson, 1978). Visualizers performed better in the analogy and the organizer condition than in the control condition, whereas verbalizers performed better in the control condition than in the two experimental conditions. There were, in general, low correlations between the different visualizer–verbalizer dimensions.

The absence of significant differences between the two kinds of analogies and a biographical introduction might warrant an explanation similar to the one in Experiment 2. According to this explanation, analogies are only effective reading aids when there is enough time to compare analogies with text concepts. Because a time limit was imposed in this experiment and the analogy condition occupied extra pages of text, subjects had no chance to do this adequately. Another explanation, however, might be that concrete analogies only work for younger subjects, as is often thought by teachers. This idea, however, runs counter to several studies by Mayer (1979a, 1979b) and others.

In this experiment low correlations appeared between the several visualizer–verbalizer dimensions. Some correlations existed only between the coding test dimensions and the questionnaire dimensions, but the other tests did not correlate with each other. This means that the tests measure different abilities and preferences (see Richardson, 1978). Further research into visualizer–verbalizer dimensions seems necessary.

Experiment 5: Connected Versus Unconnected Analogies

The aim of this experiment was to study university students while they were learning with different kinds of analogies, but under unrestricted time conditions. Two kinds of analogies—connected and unconnected—were constructed. Connected analogies refer to one domain; unconnected analogies refer to several domains.

It was hypothesized that unconnected analogies would be better encoding aids (see Mayer 1979a) because they can be chosen from different domains to fit better with the to-be-learned text. Connected analogies, in contrast, might not fit so well with the text because they should all be chosen from the same domain. However, connected analogies might be expected to act as a unifying theme that structures the learning of the text (see Ausubel, Novak, & Hanasian, 1978).

Method

Subjects and design. The subjects were 110 students from the first-year psychology course and the teacher training institute at Tilburg University. Only subjects with no prior experience in computer programming could participate. Subjects participated, either fulfilling their obligation to participate in experiments or earning 20 Dutch guilders. A pretest–posttest control group design was used, with individual random assignment to three conditions: connected analogies ($N = 45$), unconnected analogies ($N = 44$), and control ($N = 21$).

Materials. A new, introductory 1,600-word unit on computer programming (in FORTRAN) was devised for this experiment. Topics in the course were: parts of a computer, different computer languages, Read, Write, Go To, and IF Go To statements, formats, simple calculations, and differences between calculations and instructions (e.g., $N = N + 1$). At the end of the course, subjects were supposed to be able to write simple programs. Some examples of simple programs were given during the course.

Analogies were woven into the text. On top of each

page some room was left for analogies. This space was left open in the control condition. All seven connected analogies referred to a post office. Differences between calculations (2 + 3 = 5) and instructions ($N = N + 1$) were, for instance, compared with the way new balances are calculated: (new) balance = (old) balance − debits. All seven unconnected analogies were from different domains: games, crosswords, typewriters, car driving, and others. Formats were preceded by the following text:

On personal forms one sometimes has to fill in one's birthdate in a certain way in six squares, for instance 2 1 0 4 5 5. Because everyone knows this number refers to a birthdate, no one reads 210.455; everyone knows that this number should be read as 21-04-55, or April 21st, 1955. Certain rules prescribe how to read a number.

Analogies were 350 to 400 words in length. Achievement was tested by means of a test composed of 21 questions, some of which were multiple-choice, some open-ended. Fifteen questions referred directly to the text and might be called near-transfer items (see Mayer, 1975). The 6 remaining questions consisted of problems not treated in the text (far-transfer items). This test was used as an immediate posttest and a long-term retention test, but not as a pretest. Instead, 5 specific multiple-choice questions on computer programming and 5 yes/no questions on experience with computers were given as the pretest.

Procedure. This experiment consisted of 2 sessions of 90 min each. Subjects were formed in groups of 25. In the first session the pretest was administered. Following that, the actual learning took place in one room all together. Thus, differences between conditions only came out through the written texts that were different. Subjects were instructed to read the material once thoroughly. When they had finished, their reading times were recorded. Immediately afterward, the posttest was administered. When they had finished this, subjects received a filler task until all had finished reading. During the second session, which took place 1 week later, the retention test was given.

Data analysis. The data analysis was comparable with that of Experiment 4. Pretest scores were omitted from the regression analyses because subjects had no experience in computer programming and no prior knowledge. Internal consistency reliability for the posttest and the retention test were .69 (two items were removed because of negative item–test correlations).

Results and Discussion

Table 4 presents means and standard deviations for each condition on the three dependent variables. The hypothesized differences between the effects of the two kinds of analogies did not appear. The expected differences between the two analogy conditions—combined and control—were not significant, $F(1, 107) = 2.08$ and 2.63 on the posttest and the retention test respectively, both $ps > .05$. The reading time effects that were evident in previous experiments with younger subjects did not appear. Control subjects took approximately the same amount of time to read 1,600 words as experimental subjects took to read 2,000 words. Younger subjects used more time for reading the text proper for the first time when they studied with analogies than without them, but college students used no more time for text with analogies than they did for the text alone. Probably, the time spent on reading analogies was compensated for by a shorter reading time for the text itself (indirect shortening effect).

There were no differences between the two experimental conditions (connected vs. unconnected analogies). This may have been caused by an insufficiently clear difference between these conditions. The relationship between the several post office analogies may not have been clear to the subjects. In further experiments this difference should be clarified, and one should test whether subjects see them as a unifying theme or not.

Experiment 6: Active Versus Passive Comparisons

The last experiment used young children learning biology in oral lessons presented by a teacher. Aims of this experiment were: (a) to find whether analogies would facilitate children's learning at this age, (b) to compare the effects of active and passive comparisons

Table 4
Means and Standard Deviations for Each Condition (Experiment 5)

	Posttest		Retention test		Reading time	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*
Connected analogies	10.9	3.3	10.4	3.2	28.3	6.5
Unconnected analogies	11.2	3.4	10.7	3.4	28.3	6.5
Control	9.9	3.3	9.2	3.3	29.7	6.7

(active comparisons are drawn by subjects themselves, whereas teachers clearly explain the comparisons for their pupils in passive comparisons), and (c) to study the use of analogies in oral lessons.

In Experiments 1, 3, and 5, comparisons were active in that the subjects had to compare text concepts with analogous concepts, whereas in Experiments 2 and 4 explicit indications were given about these relations. In these latter two experiments, there were no significant differences between analogy and control conditions, whereas in two of the other three experiments clear differences did appear. Unfortunately, Experiments 2 and 4 differed on more grounds from the others, namely in the study time control.

Method

Subjects and design. Subjects were 163 students from 3 elementary schools in Tilburg. Ninety-four subjects were in the 5th grade, and 69 were in the 6th grade. The subjects ranged in age from 10 years to 13 years. Complete classes were assigned to the conditions so that there were 2 classes in each condition, and the classes from 1 school were in different conditions.[3] Sixty-four subjects participated in the active condition, 50 participated in the passive condition, and 49 participated in the control group.

Materials. Two lessons were selected, adapted, and extended from an existing biology course for elementary schools. One lesson treated blood circulation (veins, arteries, one-way traffic in the blood circulation, and so forth) and the functioning of the heart (ventricles, valves, parts of the heart, and so on). The other lesson treated the ingredients of the blood (red and white blood corpuscles) and their function (supply of oxygen, fighting against bacteria). Drawings of the heart and the blood circulation were supplied to the subjects.

Three analogies were provided. Contractions of the heart were compared with a whipped-cream squirter. The blood circulation was compared with a baker's route. At first a baker has many loaves of bread, but as more loaves are delivered to the customers, the baker has fewer. In most parts of the baker's route there is one-way traffic. The four kinds of ingredients of blood were compared with white knights (white blood corpuscles), red knights (red blood corpuscles), black knights (bacteria), and bricklayers (blood platelets). White knights fought against the black ones while the red knights supplied food and weapons and the bricklayers repaired holes in the castle.

In the first lesson there was no difference between the active and passive condition (this was not possible because of the kind of analogy used). In the second lesson the teacher explicitly made all comparisons, in the passive condition. The teacher said, for instance, "The bricklayers are like the platelets because they repair." In the active condition subjects were instructed to look for these relations themselves.

Two 10-item achievement tests (one per lesson) were constructed. They consisted of multiple-choice and open-ended questions. These were used as a pretest, a posttest, and a retention test. Furthermore, 11 items were constructed that tested the ability of the subjects to compare text concepts with analogous concepts (control tests). Analogical reasoning ability was tested by means of a subtest of a standardized Dutch intelligence test, known as the Differential Abilities Test.

Procedure. The experiment consisted of four sessions during regular school time. All lessons were given by a psychology student with teaching experience, and they were tape-recorded by an assistant. Plans were devised for all lessons, and they were as similar as possible. During the first session the pretests and the analogical reasoning test were administered. In the second session (1 week later), the first lesson and the first posttest were completed. During the third session (1 week later), the second lesson and the second posttest were completed. The control tests were also administered. In the final session (3 weeks later), the retention tests and the control tests were administered.

Data analysis. Because no random assignment to conditions in this experiment was possible, there was a greater need to check for preexisting differences between conditions. Fortunately, the floor effect that was observed in previous experiments did not appear in this one. Thus, pretest scores could form the first predictor in the generalized regression analyses. Means and standard deviations on the combined pretests were 9.3 and 1.6, respectively, for the control condition, 9.0 and 1.5, respectively, for the active condition, and 9.5 and 1.9, respectively, for the passive condition.

Results and Discussion

There were no significant adjusted mean differences between active and passive conditions on either the combined posttest or combined retention test, both $ps > .10$. Differences between analogy conditions combined and the control condition were significant on both the posttest and the retention test, $Fs(1, 159) = 5.87$ and 10.48, $ps < .01$ (one-tailed), respectively. Explained variances were 3.8% on the posttests and 6.0% on the retention tests. Adjusted means on the combined posttests were 14.9 ($SD = 2.9$) for the control condition, 15.6 ($SD = 2.6$) for the active condition, and 16.4 ($SD = 2.1$) for the passive condition. Adjusted means on the combined retention tests were 12.1 ($SD = 3.1$), 13.5 ($SD = 2.6$), and 13.7 ($SD = 2.8$), respectively.

The lessons lasted an average of 16.5 min

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[3] Treatments were administered to classes (two per condition), whereas the analysis is based on students. As a result, potential units of analysis problems should be considered when interpreting the findings.

in the control condition, 21.0 min in the active condition, and 20.5 min in the passive condition. The differences among the three means were significant, $p < .05$.

This last experiment complements the results of the previous ones by demonstrating that elementary school students may also benefit from analogies presented in oral lessons. Obviously, the problems that children often encounter with analogical reasoning (see Ortony, Reynolds, & Arter, 1978) did not occur. Subjects performed well on the control tests and clearly benefited from the analogies.

The analogies in this experiment required extra instructional time. Whether this time investment is worthwhile depends, in this author's view, on the subjective estimation of the relationship between time investment and performance gain. Central questions in further research should be: (a) Can more useful instructional activities be performed in this extra time? (b) How much time is available? (c) Is it possible to reduce instructional time spent on analogies and still retain performance gain? (d) Is performance sufficiently low that improvement is necessary?

General Discussion

Five research questions were asked in the introduction to this article. The answers to these questions are formulated in this final section.

1. Does the addition of concrete analogies lead to improved performance in elementary and secondary school pupils and in college students?

The answer to this question is affirmative. Significant results were obtained in three of the experiments. These results were obtained with different kinds of subject matter (science, biology) and under different comparison conditions (analogies available or not, active vs. passive comparison). Few differences were found among different kinds of analogies (connected vs. unconnected, passive vs. active comparison), with one exception: Comparative organizers led to better results (in college students) than did concrete analogies. It is remarkable that in several of the experiments significantly better results were obtained when subjects were learning with analogies in spite of the rather low performance on those control tests, which were designed to determine whether subjects could relate analogies and text concepts. Several attempts to improve results on control tests failed. Better control test results were obtained only in the experiment that used the youngest subjects, probably because of the influence of the oral presentation of the lessons. Perhaps training in the use of analogies in learning might result in the sought-after improvements on control tests (and in improved performance on achievement tests).

2. Does the addition of analogies lead to extended reading time (direct and indirect effects)?

Among secondary school students, analogies led to direct (reading analogies) and indirect (comparing analogies with text) lengthening effects. This indirect effect occurred during the first reading, but was compensated for by an indirect shortening effect during the second reading (see Experiment 3). The amount of lengthening differed between Experiments 1 and 3. With older students (Experiment 5), no indirect lengthening effect occurred, because the direct lengthening effect had already been compensated for during the first reading by an indirect shortening effect, resulting in equal total study times. In some experiments the extra time investment seemed rather large in comparison with the performance gain (Experiment 1). In others, however, the opposite was true (Experiments 3 and 6).

3. What are the effects under restrictive time conditions?

Under these restricted conditions, no differences occurred between conditions with and without analogies (Experiments 2 and 4), except for the comparative organizer condition (Experiment 4). Thus, analogies do not form efficient reading aids in the traditional sense. This result was ascribed to the fact that they are only effective when there is enough time to read them, and enough time to compare them with text concepts.

Analogies might still be considered efficient reading aids when extra time investment is compensated for by higher performance. This kind of efficiency, however,

cannot be detected with a design incorporating restricted time limits.

4. Are there aptitude-by-treatment interactions?

Many hypothesized ATIs did not prove to be significant. No ATIs were found regarding field independence, attitude toward mathematics, pretest scores, analogical reasoning ability (with one exception), age (within and across experiments), and school type. Inconsistent results appeared with respect to operation learning and comprehension learning styles. In one experiment significant interactions were evident that were not replicated in the next experiment. The most interesting ATIs involved the visualizer–verbalizer dimension, although some of these interactions were also inconsistent. Remarkably, these interactions appeared in experiments with time restrictions. Finally, it should be mentioned that almost no prior knowledge existed in all experiments (but see Experiment 6). Interactions with prior knowledge may, therefore, be expected with subjects who have more prior knowledge.

5. Why are analogies effective?

Three functions—concretizing, structurizing, and active assimilation functions—were mentioned in the introduction as explanations for the effectiveness of analogies in learning. It may now be concluded that all three explanations are supported by the data of the experiments. Indications for the concretizing function result from the significant interactions with visualizer–verbalizer dimensions (Experiments 2 and 4). The structurizing explanation was supported by the (inconsistent) learning style interaction (Experiment 1), but especially by the relation test results in Experiment 3. Subjects learning with analogies had a better idea of the relationship between concepts than did subjects learning without them. The active assimilation explanation, deduced from the theories of Mayer (1979a, 1979b) and Wittrock (1979), was supported by the following findings: (a) subjects in Experiments 1 and 3 used more time for the first reading of a text when they were instructed with the aid of analogies, (b) results regarding certain dependent variables (comprehension test, transfer test, relation test) were clearer than for knowledge tests, and (c) analogies were effective reading aids for subjects without prior knowledge.

What does this mean for educational practice? Analogies are effective reading aids under certain conditions and for certain kinds of subjects. However, doubts still exist concerning their efficiency. Consequently, I propose that more analogies should be added to texts and oral lessons, but it should be done in such a way that subjects are free to decide for themselves whether they wish to use them.

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