

known information; (c) the analogical information is new, but is easier to learn (or understand) than the to be learned information (for instance, because it can be easily assimilated to prior knowledge, or because it is familiar to the learner); (d) the analogical information is more concrete than the to be learned information (for instance, because it can be demonstrated, pictured or taken apart). The analogies we used in our experiments met the last three conditions, thus as far as the information presented was known to the subjects, this knowledge was directed at the task at hand. As far as it was not known, it was easier to learn because it was more concrete and more familiar to the learners.

The analogies we used were of a rather broad type. In some experiments we compared several electricity concepts (current, voltage, resistance, conductivity, etc.) to several water-flow concepts. In other experiments, we compared the behavior of electrons in a wire to the behavior of a group of children entering a restaurant, each searching for a chair. In another experiment the structure of a computer was compared to the structure of a post-office. Finally, assimilation and accommodation in cognitive structures were compared to adaptation processes in a football-team.

FUNCTIONS OF CONCRETE ANALOGIES

Various theorists have proposed different reasons why the presentation of analogies might be an effective learning-aid. Some theorists stress that analogies make abstract information imaginable, concrete and vivid (Davidson, 1976; Ortony, 1975). Others, however, stress a completely different function, that being a structuring function (e.g. Norman, 1978; Rumelhart and Ortony, 1977). This second group stresses that in learning via analogies an existent schema is used as a kind of formal structure in which new information is absorbed. The existent schema may aid students in comprehending the structure of the new text. A third function of analogies stems from the assimilation-integration theory of Mayer (1979a,b) and from the generative meaning theory of Wittrock (1979). According to Mayer, analogies may induce an integrative assimilation process (at least under some conditions) which lead to qualitatively different learning-outcomes (Mayer and Bromage, 1980). Likewise Wittrock (1979) stated that the effectivity of learning depends on the number and kind of transformations which a learner performs. In some cases analogies may stimulate learners to transform information more deeply and more actively.

Apart from these possible positive functions of analogies, in our view, several possible drawbacks of their use can be discerned. These drawbacks have been distilled from discussions with practicing teachers and, occasionally, from the educational literature (e.g. Miller, 1976; Davidson, 1976). Drawbacks of analogies in texts seem to be of the following nature: (a) they may confuse pupils, especially younger ones; (b) they may create cognitive distortion (Davidson, 1976); (c) they may be superfluous (cf. Parkhurst, 1975); (d) they may require the use of extra learning-time; (e) they may block real understanding of abstract information causing pupils to get stuck on a concrete level without ever reaching the level of abstract insight; and (f) they may strengthen a concrete attitude of pupils.

PRIOR RESEARCH

Most of the prior research on concrete analogies as aids in learning has

been directed at the effectivity question: "Does learning with the aid of analogies cause better learning results?". Results of these studies were, in general, rather clear. The majority of the investigators found significantly higher results for learning with than without analogies (Scandura and Wells, 1967; Lesh (cited in Mayer, 1979b); Mayer, 1975, 1976, 1978, 1979a,b; Rigney and Lutz, 1976; Royer and Cable, 1975, 1976). Exceptions were the studies of Bell and Gagné (1979) and Devine-Hawkins (cited in Davidson, 1976). Some investigators (particularly Mayer) found support for the contention that analogies also bring qualitatively different results (especially Mayer and Bromage, 1980). Furthermore some aptitude-treatment-interactions with intelligence as aptitude were found (Mayer, 1975; Bell and Gagné, 1979).

When compared to results of other fields of research in educational psychology (i.e. advance organizers, Barnes and Clawson, 1975), the results of these studies on analogies seem rather consistent and clear. The number of studies, however, was rather small and the research was in some ways limited. For one thing, almost all of the studies employed college students (exception: Rigney and Lutz, 1976). Furthermore, no research was done on the efficiency question (cf. Faw and Waller, 1976), nor did any investigator take reading-time effects into account (exception: Scandura and Wells, 1967). Finally, in most studies very short texts were used. Many prior studies have been directed at questions raised by Mayer's assimilation theory (see for a review Mayer, 1979a, b). No research, however, has been directed at the other two discerned theoretical functions of concrete analogies, that being their concretizing and structurizing functions. Our research, described in this paper, aimed at filling in the described gaps. Thus, our experiments were carried out with younger subjects and relatively long texts. Furthermore, the two other functions of analogies were investigated (see below) and much attention was given to reading-time and efficiency.

A VIEW ON READING-TIME

Analogies (and other reading aids) may exert three different kinds of influence on reading-time. Analogies may directly influence reading-time because of the extra words involved. Analogies should be read by the subjects and this reading will take time. Though this direct effect on reading-time was investigated in research on other reading aids (i.e. advance-organizers cf. Faw and Waller, 1976), as yet no research on direct reading-time effects of analogies has been done. Apart from these direct effects, however, one can discern two kinds of indirect effects. These indirect effects were neither controlled for nor measured in prior research on analogies or reading aids in general. This omission is a very serious one, because indirect effects may confound results (this view is exposed more fully in my dissertation (Simons, 1980) and in Simons (in preparation)).

The first indirect effect may be called an indirect lengthening-effect. Reading aids may cause subjects to study the text longer (this apart from the direct effect). For example, because analogies may stimulate a different kind of processing behavior in the reader (i.e. more actively, more deeply, in a comparative way), the text as such may be processed in a slower tempo than a text without analogies. The second indirect effect is an indirect shortening of reading-time. Reading aids may facilitate the reading of the text as such (this is exactly why they are constructed!), causing an increase in the reading-tempo. For example, because of the presence of an analogy a subject might understand a text sooner than when this analogy is lacking and thus be able to read the text more quickly and easily.

One might object that these two indirect effects are controlled in normally used experimental designs, in which experimental and control groups are allotted the same (nominal) amount of time. This objection, however, is wrong. Equal-time-allotment is no guarantee that indirect effects are controlled for when time-limits are broad. In almost all prior experiments on reading aids (for good reasons) broad time-limits were imposed. Therefore, many subjects will not have used all of the permitted time. Thus, results of prior experiments may have been confounded by indirect effects: significant differences in results may have been caused by an indirect lengthening of reading-times and non-significant differences by an indirect shortening. All of this leads to the proposition that it is better not to try to control indirect effects, but rather that one should carefully measure reading-times under free-time-conditions and take them into account.

RESEARCH QUESTIONS AND HYPOTHESES

The experiments, summarized here, were directed at answering the following questions:

- (1) Does the addition of concrete analogies to texts lead to higher performances in elementary and secondary school pupils?
- (2) Does this addition of analogies lead to longer reading-times (direct and indirect effects)?
- (3) What are the effects under restricted-time conditions?
- (4) Are there aptitude-treatment-interactions?
- (5) What functions do analogies have in learning from texts? Or stated differently: "Why are analogies effective?"

As to the last question (why?) the following hypotheses were formulated:

- (a) If concrete analogies function to make texts more imaginable, then an interaction-effect as to a visualizer-verbalizer dimension should show up.
- (b) If concrete analogies help subjects to get a better impression of the (formal) structure of subject-matter, then an interaction-effect as to a structurizing-style should be significant and subjects should have a better view of the structure of the subject matter.
- (c) If concrete analogies lead to a different kind of processing (i.e. more actively, more deeply), then the following effects will appear: (1) an interaction-effect as to general intelligence and advance-knowledge; (2) differences in reading-times (different processing might take different time); (3) effects on certain dependent variables (comprehension, transfer).

METHOD

In each of the six experiments 80 - 100 subjects participated. Subjects were from secondary schools (3 experiments), elementary schools (1 experiment) and college students (2 experiments). All experiments consisted of 3 or 4 sessions of 2 hours each. During the first session a pretest was administered consisting of items from the posttest. Furthermore, subjects were administered certain "background gathering" tests (different per experiment). Structurizing style, for example, was measured via the use of Pask's Spy Ring History Test (Pask, 1976) and via the Hidden Figure Test. The visualizer-verbalizer dimension was measured via procedures designed by Boekaerts (1979) and Richardson (1978). Intelligence was measured via an analogical-reasoning-ability-test.

In the next session(s) subjects studied (read) texts of approximately 20 pages on electricity (3 experiments), the theory of Piaget, computer-programming

and the human blood system. Subjects were assigned randomly to either of two or three conditions. In one or two conditions, texts were extended with concrete analogies (see the introduction). The other condition was a text only control condition. In some experiments subjects were required to read the text several times, registering their reading-times each time they finished a reading. Sometimes direct effects of analogies were measured separately by presenting them apart from the text. At other times the analogies were woven into the texts. In other experiments the so called efficiency method was used (Peeck, 1977). In this method experimental subjects are allowed the same amount of time to study a text plus analogies as control subjects have for the text only. After the learning-phase different achievement-tests were administered (comprehension, transfer, knowledge) and different control-tests (use of analogies, knowledge of analogies). In one experiment a relation-test was given to the subjects (Lodewijks, 1981). In this test subjects must rate all possible pairs of concepts as to their relatedness. These ratings are compared to expert ratings. Two scores emerge from this test, a reproductive (rep) and a productive (prod) score. Rep denotes the extent to which a subject reproduced the relations exposed in the text. Prod relates to the extent to which a subject produced relations between concepts that were not stated explicitly in the text, but were considered important by the experts. The last session was devoted to a long-term-retention-test and to the debriefing of the subjects. Data were analysed by way of regression-analyses (Kerlinger and Pedhazur, 1973).

RESULTS

PERFORMANCE EFFECTS

As to the first question (higher performances under unlimited time conditions?), results indicated on all dependent variables differences in favour of the learning with analogies, though these differences were not always significant. (See the results of one experiment in Figure 1).

In this experiment significant results were obtained on the first comprehension-test ($F=6.79$; $p<.05$) and on the factual-detail-test filled in after three weeks ($F=4.72$; $p<.05$). Results on the other two dependent measures were not significant (F -values of 2.28 and 2.65).

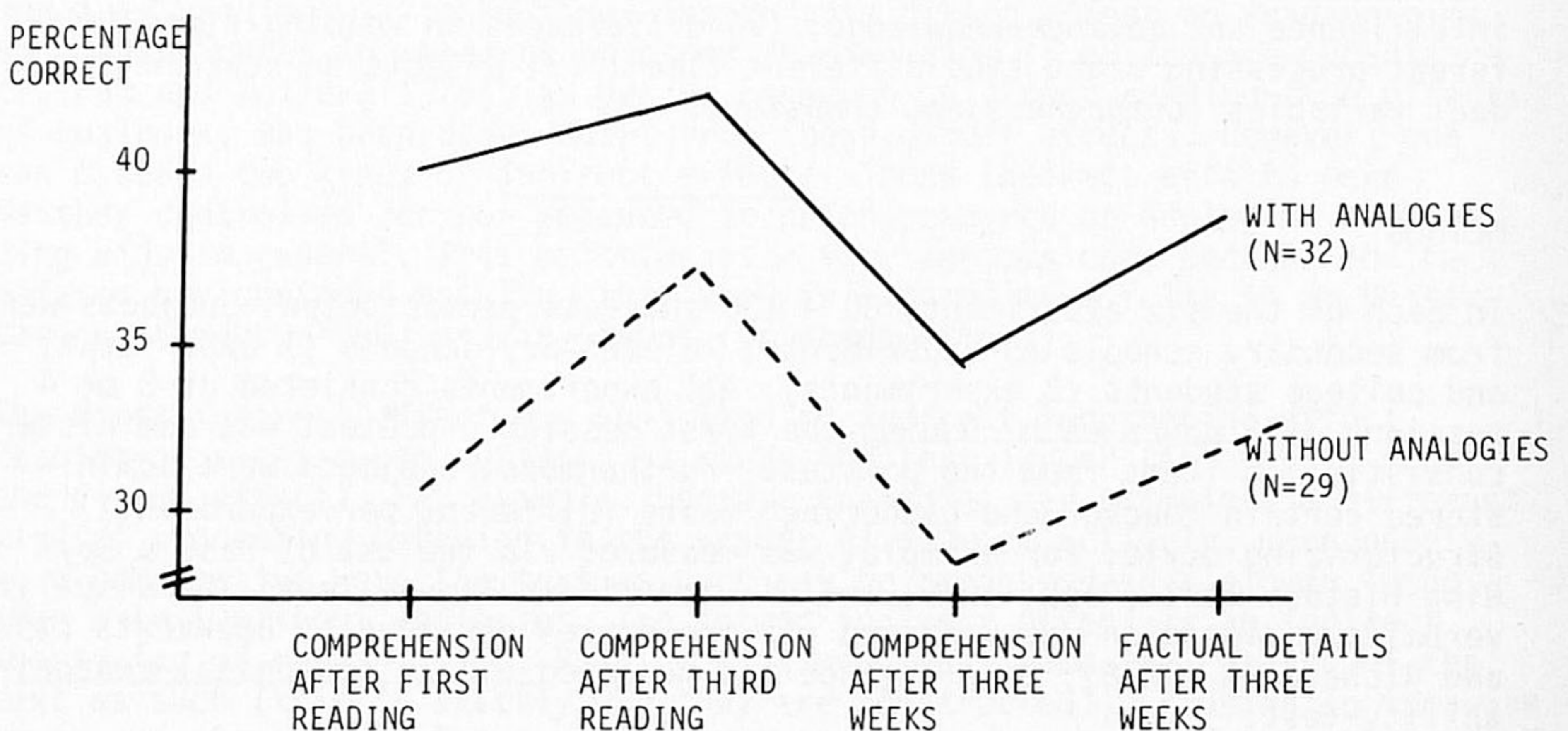


Figure 1
Results on 4 dependent variables in an experiment with 61 secondary-school-children learning science

There was no support for the contention that analogies only lead to higher far-transfer and comprehension results and not to higher factual-knowledge. On all three kinds of performance-measures significant and non-significant differences were found. Subjects learning with the help of analogies had a significantly better view of the structure of the concepts, as measured by the relation-test ($F(1,80) = 7.05$; $p < .01$; 8.1% variance).

TIME-EFFECTS

Results as to time-spending were different for younger and older subjects. Secondary-school-pupils spent both time to read the extra text on the analogies (direct effect) and more time on the text as such (indirect effect). Indirect lengthening of reading-time occurred during the first-reading of the text (significant in one experiment, not in a replication-study). Also indirect shortening of reading-time occurred during the second and third reading (non-significant in the first experiment, significant in the replication-study). These indirect effects are illustrated in Figure 2 (first experiment). The first reading took significantly more time in the condition with analogies ($F=33.06$; $p < .01$). No significant differences were found on the second and third reading ($F=1.10$, n.s.).

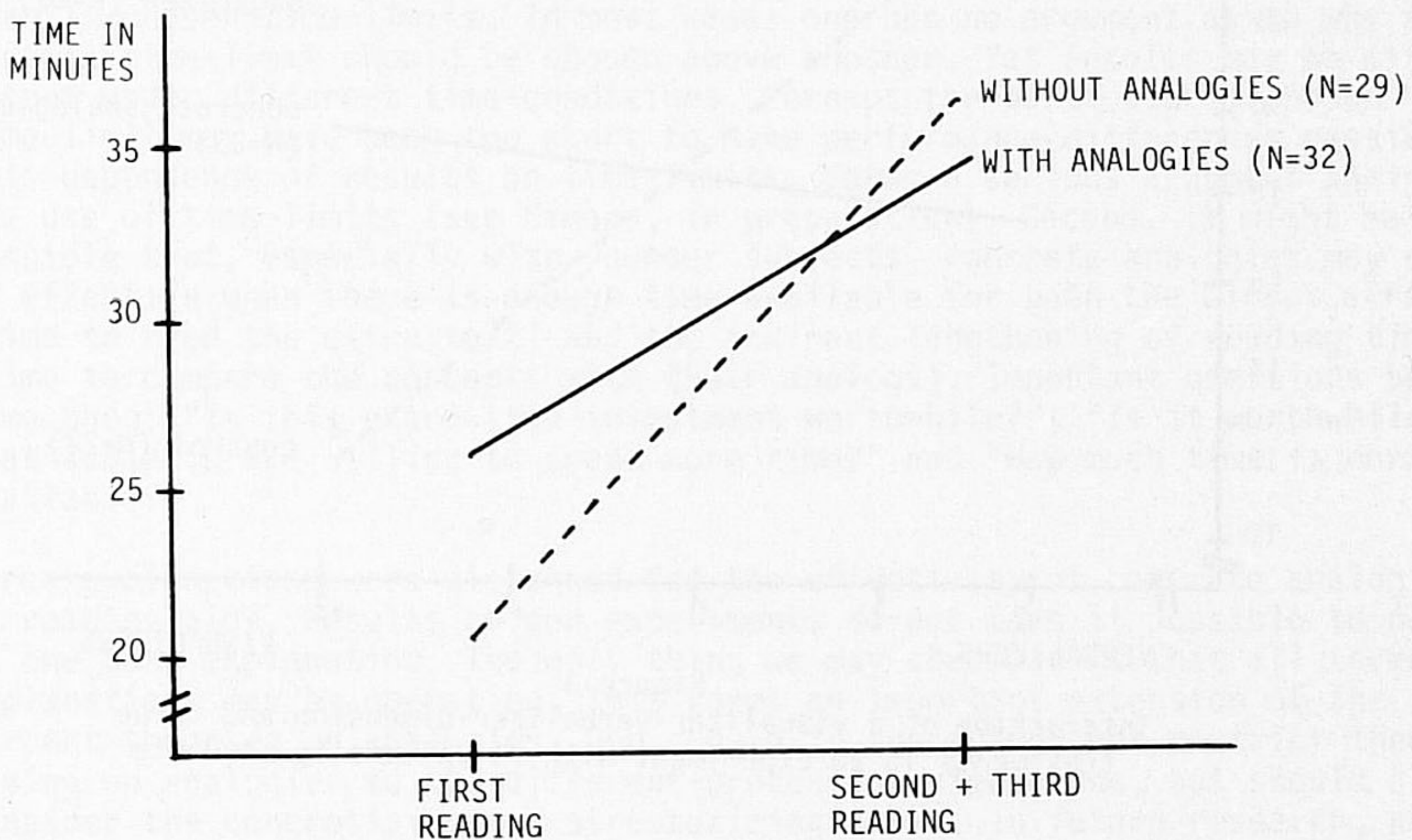


Figure 2
Reading-times in an experiment with
61 secondary-school-children learning science

With college students different results as to time spending appeared. Experimental subjects used approximately the same amount of time to study the analogies (400 words) and the text as the control subjects did for the text only. Thus, an indirect shortening of reading-time compensated for direct and/or indirect lengthening effects.

RESTRICTIVE TIME CONDITIONS

In two experiments restrictive time-limits were imposed. In these cases no significant differences between learning with and without analogies were

found. Thus, learning with analogies does not seem to be more efficient than learning without. These results, however, contrast with the results of the other experiments where no time-limits were imposed. In these cases, statistical control of time-variations by way of regression-analysis did not make performance-differences disappear (see further the discussion section).

APTITUDE-TREATMENT-INTERACTIONS

Several significant aptitude-treatment-interactions were found. In two experiments (interestingly enough these were the experiments with time-limits) interactions of the treatment (with or without analogies) and visualizer-verbalizer-dimensions were significant ($F=6.69$; $p<.05$). These interactions accounted for 10-15% of the variance (see Figure 3).

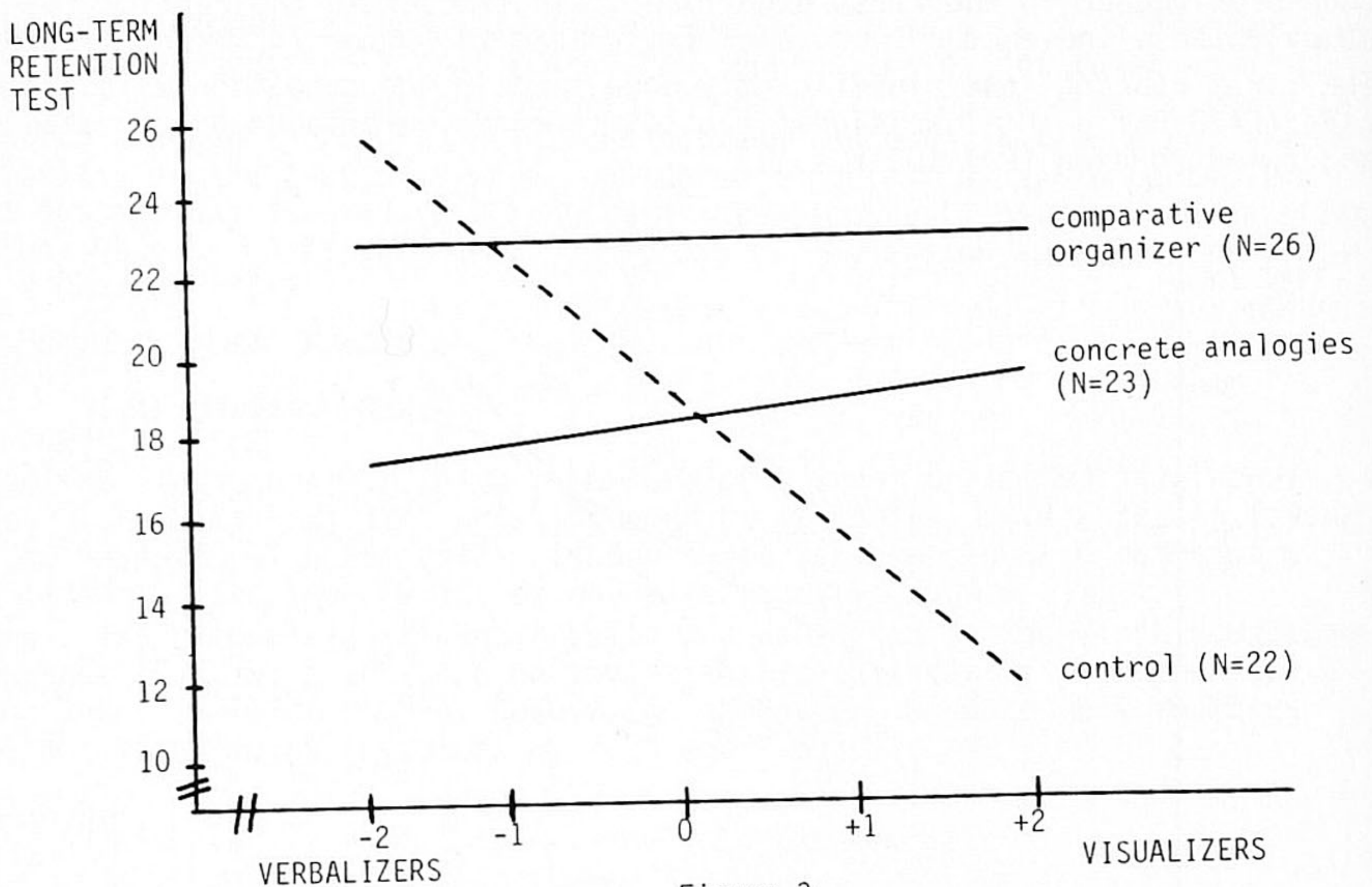


Figure 3
Interaction of a visualizer-verbalizer-dimension and three treatments in an experiment with 71 university students

Also, interactions with the structuring-style dimension proved to be significant (14.5% of the variance; $F(1,57) = 10.62$; $p < .05$). This last interaction, however, did not reappear in a replication-study. Inconsistent results were also found in reference to general intelligence: In one experiment a significant interaction was found (elementary school subjects), in other experiments, however, this result was not replicated. The following characteristics of subjects did not interact with the treatments: field(in)dependence, age, pretest, type of school and attitude towards mathematics.

WHY ARE CONCRETE ANALOGIES EFFECTIVE?

All three of the hypotheses on the why-questions found support in the data. The concretizing explanation was given credence through the appearance of

the significant interactions with the visualizer-verbalizer dimension. The structurizing explanation was supported by the (inconsistent) interaction with the structurizing-style and by the results on the relation-test presented above. Several of the results were in agreement with the different-processing-hypothesis (assimilation-integration-theory and generative meaning theory). Both results on reading-time (analogies caused slower reading in secondary-school children) and results on comprehension and transfertests (not elaborated here) support this hypothesis. Furthermore, all of our subjects had no advance-knowledge of the subject matter. That significant main-effects of analogies were found with subjects without advance-knowledge, agrees with the different processing explanation (cf. Mayer, 1979).

DISCUSSION

Though it has been shown that concrete analogies are effective learning aids, their efficiency appears to be questionable. In the experiments with time-limits, no differences between learning with and learning without analogies could be shown. On the other hand in two of our experiments without time-limits, differences remained significant after partialing out time-variance. This discrepancy may be solved in the following two ways. First, one should realize that results under restrictive time conditions depend upon arbitrarily chosen time-limits. In most cases one has no argument as to why a certain time-limit should be chosen above another. Yet results may be different under different time-conditions. Perhaps the particularly chosen time-limit may have been too short to make performance differences possible. This dependence of results on time-limits, forms a serious argument against the use of time-limits (see Simons, in preparation). Second, it might be possible that, especially with younger subjects, concrete analogies may only be effective when there is enough time available for both the direct effect (time to read the extra text) and the indirect lengthening of reading time (time to compare the concepts with their analogs). Important questions become then: "Is this extra time-investment worthwhile?"; "Is it worthwhile that subjects are willing to spend more time?" and "How much time is normally available?"

Three explanations were discerned for the effectivity of concrete analogies as reading aids. Results of our experiments do not make it possible to point to one best explanation. The only thing we may conclude is that all three explanations may be operating. This forms an important extension of the current theories on analogies. One should in the future not restrict theorizing on analogies to the different-processing-view alone, but should also consider the concretizing and structurizing views. In future research, analogies might be designed in such a way that they may trigger one of the three functions specifically (concretizing analogies vs structurizing analogies etc.).

The conclusions as to the "why" question should be viewed in proper perspective. Necessarily, these conclusions should be made cautiously because of the distance between data and conclusions. We only found indications, not firm evidence. The conclusions, for instance, that analogies make a text more imaginable because the interaction with a visualizer-verbalizer-dimension was significant remains to be checked against an imagery-control: Is this interaction indeed to be explained in terms of better imaginability of phenomena or concepts? This could be checked by way of a questionnaire. Finally, we would like to discuss a practical implication of all of this. Because analogies were effective under some conditions (e.g. time) and for

some types of students (visualizers), but ineffective under other conditions and for other types of students, differentiation seems necessary. It does not make sense to make special books with analogies for visualizers and others without them for verbalizers. The data-base for such an implication is still too weak. Furthermore, it is not as yet possible to measure these individual differences in a practical setting. Instead, more concrete analogies should be included in text books than is done thus far, but these analogies should be placed in such a way that subjects are free to either use them or not.

NOTES

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