

Understanding the Role of Analogies in Restructuring Processes

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Abstract

An experiment is presented which investigated the role of analogies in restructuring processes involved in understanding counter-intuitive expository text. The expository text presented different explanations of the day/night cycle, with or without the use of analogy. We expected that the simple presentation of the scientific explanation of the day/night cycle would not be sufficient to help children change their initial explanatory framework and that the use of analogy would be more effective. One hundred and eleven elementary school children participated in the study (56 3rd graders and 55 5th graders). The results confirmed our hypothesis that it is easier to recall information which is consistent with prior knowledge than the opposite. They also showed that analogy can play a positive role not only in the recall of counter-intuitive information but also in achieving small but significant changes in existing explanatory structures.

Introduction

The present study investigates the influence of analogy in the comprehension and recall of expository text. The expository texts used presented explanatory information which was either compatible with prior knowledge (thereafter ‘initial text’) or incompatible with prior knowledge but compatible with currently accepted science. In the latter case, there were two kinds of scientific text: One without an analogy—(thereafter ‘scientific text’) or with an analogy (thereafter ‘analogy text’).

Prior research has shown that readers find it difficult to comprehend information contained in expository texts when this information is incongruent with their prior knowledge (see Dole, 2000 for a review). The use of analogy to facilitate the understanding of counter-intuitive information has been investigated by a number of researchers, yet it is not yet clear how exactly it contributes to conceptual change process in text comprehension (Brown & Clement, 1989; Chiu & Lin, 2005; Dagher, 1994; Duit, 1991; Gentner, 1983; Wong, 1993; Vosniadou & Ortony, 1989). The purpose of the present study was to investigate in greater detail the processes thereby which young readers map counter-intuitive information into the knowledge base and the role of

analogy in this process, in the context of Vosniadou’s framework theory of conceptual change (Vosniadou, 1994, 2006).

All expository texts used presented an explanation of the day/night cycle, in terms of the sun going down behind the mountains and the moon coming up (initial text), or in terms of the earth’s axis rotation (scientific text), or in terms of an analogy to a ‘gyros’, a meat roasting vertical rotisserie (analogy text).

Previous studies investigating the development of children’s cosmological knowledge have shown that young children have considerable difficulties in conceptualizing the earth as a sphere whose rotation around its axis causes the day/night cycle (Vosniadou & Brewer, 1992, 1994). Usually, they start with an explanation of the day/night cycle based on the up/down movement of the sun and the moon according to which night happens when the sun disappears behind the mountains or clouds and the moon comes up. The moon is often implicated causally in this type of explanation.

An initial explanation of the day/night cycle is structurally very different from the scientific explanation according to which the alteration of day and night happens because of the earth’s rotation around its axis. It appears that children have difficulty in immediately restructuring their explanatory frameworks when exposed to the above-mentioned scientific information. Rather, they construct various kinds of intermediate interpretations or models, which reveal their attempts to assimilate aspects of the scientific information to their prior knowledge (see Vosniadou and Brewer, 1994). For example, children often change their initial explanation of the day/night cycle from one according to which the earth is stationary and sun and the moon move up/down, to an explanation according to which the earth is moving up/down and the sun and the moon are stationary and located at diametrically opposite locations. In this model, the sun is conceptualized to be ‘up’ in a part of the sky where there is always day, and the moon is thought to be ‘down’ in a part of the sky where there is always night, playing a causal role in the day/night cycle.

The present study aimed at investigating the influence of analogy in the restructuring processes required in the comprehension of counter-intuitive, expository text. More specifically the following

hypotheses were made: First, we hypothesized that the comprehension and recall of the initial text would be easier than the comprehension or recall of scientific text, because of the greater compatibility in explanatory structure between the initial text and children's prior knowledge. As a result, we expected a greater number of idea units recalled and a smaller number of distortions for the initial text compared to the scientific text.

Second, we hypothesized that the analogy could help in the restructuring processes because it would present the new and unfamiliar explanatory structure drawing upon children's prior knowledge from a different domain. Thus, we expected a greater number of idea units recalled and a smaller number of distortions for the scientific text with analogy compared with the scientific text without analogy.

In order to be able to understand whether the children were constructively using the information presented in the text to change their prior knowledge, we started out by asking children to provide an explanation of the day/night cycle (pre-test), both verbally and in a drawing. Consecutively, the same children were presented with an expository text (initial, scientific, or analogy) and were asked to recall it. At the end the children were asked to provide an explanation of the day/night cycle again, both verbally and in a drawing. Our dependent measures included the following: 1) Number and kind of idea units recalled from the expository text; 2) number and kind of distortions of idea units in the expository text; and 3) changes between pre and post test explanations of the day/night cycle. The change in explanation was scored in terms of a) verbal expressions used, b) drawings, and c) mechanisms for explaining the day/night cycle (e.g. up/down movement of the sun. vs. up/down movement of the earth, etc.), scored as changes from initial to alternative to scientific explanations.

Method

Participants

One hundred and eleven children participated in the study. They came from two elementary schools in a middle-class suburb of Athens, Greece. Fifty six students attended 3rd grade and their mean age was 8 years and 8 months. Fifty five students attended 5th grade and their mean age was 10 years and 5 months.

Materials

Three kinds of expository texts were written for the purposes of this study. All texts were presented from the point of view of a hypothetical child (e.g., 'Paul believes that the earth does not move, etc.). The initial text described the earth as stable and explained the day/night cycle as the result of the sun's and moon's up/down movement behind the mountains. The scientific text presented the earth's rotation around its

axis as the explanation for the day/night cycle, causing the sun's light to fall on different parts of the earth. The Earth was presented as spherical and it was explicitly mentioned that the moon has no causal role in the day/night cycle. The analogy text was based on the structural similarity between the axis rotation of the earth and the east/west rotation of gyros – meat roasted on a vertical rotisserie commonly found in Greek restaurants. It was explicitly mentioned that the earth rotates around its axis just like gyros turns around on the vertical spit while roasting. Day happens when the sun shines on the part of the earth that faces it, just like in gyros, where the fire cooks the part of the meat that faces it. The gyros analogy was chosen because of its great familiarity to young Greek children. The structural mapping of the two mechanisms was made explicit.

The initial and scientific texts were of similar lengths (114 and 120 words respectively) and they were also counterbalanced, controlling for number and type of sentences. The analogy text was longer (177 words), but also counterbalanced with the initial and scientific texts.

In the pre and post tests the children were first asked to make a drawing of the earth ('Draw a picture of the earth and of a child living on the earth and make it so it is daytime for this child. Please, show in your drawing where the sun is during the night'). Then they were asked to give a verbal explanation of the day/night cycle ('Can you explain how day changes to night?')

Procedure

The pre-test was administered first as a group test in the classroom. Then, the children were given copies of one of the three texts to read. The three 3rd grade and three 5th grade classrooms were randomly assigned to one of the experimental conditions. The experimenter read the text aloud to children. Then children had 5 minutes to read the text on their own. The experimenter responded to clarification questions only. Then she removed the text and presented the children with the recall question ('Please write as much information as you can recall from the text that you read'). The post-test was administered last.

Results

Recall

The idea units recalled by the children from all text type were collected (two scorers, reliability 96%) and were assigned one point each. The scores were subjected to a two-way ANOVA [grade (3rd*5th) * text (initial*scientific*analogy)]. The results showed statistically main effects for grade [$F(1,111)=19,007, p<.001$] in favor of the 5th graders and for text type [$F(1,112)=3,393, p<.05$] in favor of the initial text and the analogy text over the scientific text. As can be seen in Figure 1, the 5th graders were able to recall more information from all the texts than the 3rd

graders. The initial text was easier to recall for both age groups than the scientific text, and the scientific text with analogy was considerably easier than the text without analogy. Thus analogy had the expected facilitation effect on the recall of idea units.

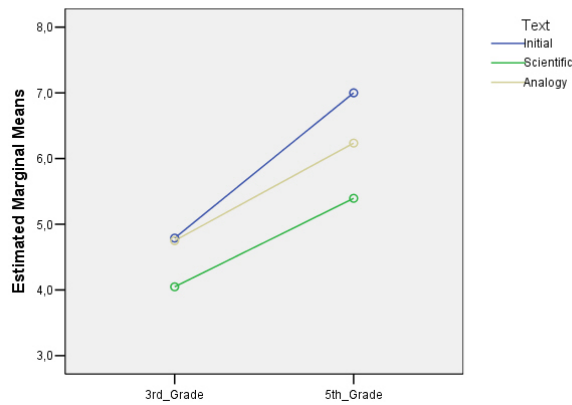


Figure 1: Mean idea units recalled as a function of text and grade

Distortions

The analysis of the distortions appearing in children’s recalls is still in progress. In a preliminary count we have collected all relevant distortions (two scorers, reliability 89%), and subjected them to a two-way ANOVA [grade (3rd*5th) * text (initial*scientific*analogy)], which showed no statistically significant effects. Figure 2 shows the results of this analysis.

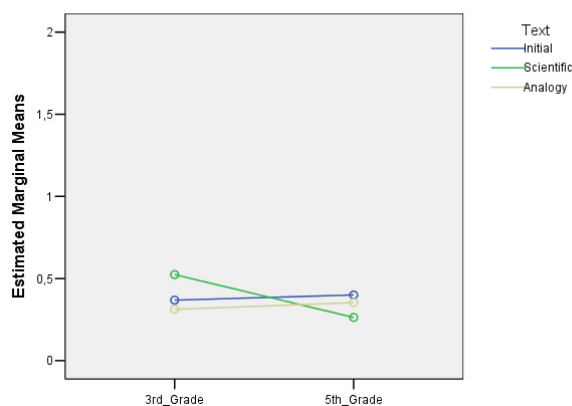


Figure 2: Mean scores for number of distortions created as a function of text and grade

Our next step was to categorize the distortions into distinct types. This analysis showed different kinds of distortions for the different kinds of texts. In the case of the initial text, our data showed that some children

created distortions which we categorized as ‘inversions of causality’. All of these children presented the movement of the sun and the moon as a result of the day/night cycle rather than its cause, as it was stated in the text. For example, they said that ‘When it turns night, the sun goes behind the mountains’, rather than ‘Night happens because the sun goes behind the mountains’ (*Inversion of Causality*). An examination of children’s explanations of the day/night cycle in the pretest (prior to their exposure in the initial expository text) showed that all of these children were familiar with aspects of the scientific explanation of the day/night cycle. Thus, for these children the initial explanation was counter-intuitive and the inversion of causality could be interpreted as an attempt on their part to align the counter-intuitive information with their prior knowledge.

Regarding the scientific and scientific plus analogy texts, the children created several distortions which revealed their difficulties in understanding the scientific mechanism of the day/night cycle. For example, they said that the day/night cycle happens because the earth revolves around the sun (Errors in describing the movement of the earth), or that the moon causes the night (Causality of night on Moon), or that the Sun and/or Moon move up/down or revolve around the Earth (Change of causality from earth moving to sun/moon moving), distortions which are similar to several common misconceptions of the day/night cycle observed in prior research (Vosniadou & Brewer, 1994).

Table 1: Preliminary Categories of Distortions

Category of Distortion	Grade					
	Initial		Scientific		Analogy	
	3 rd	5 th	3 rd	5 th	3 rd	5 th
1. Inversion of causality	5	7	1	1	-	-
2. Change of causality from earth moving to sun/moon moving	-	1	4	0	3	2
4. Causality of night on Moon	-	-	4	3	-	2
5. Errors in describing the movement of the Earth	-	-	1	1	1	2
6. Other	1	-	1	-	-	-
No distortion	13	12	10	14	12	11

Influence of Text type on Children’s Explanations: Pre and Post-Test Comparisons

In an attempt to investigate how the different text types influenced children’s explanations of the

day/night cycle, we looked at changes in children’s verbal and pictorial explanations from the pre to the post-test. These explanations were categorized as ‘scientific’ if they were consistent with the scientific explanation (e.g., earth’s axis rotation), as ‘initial’, if they were consistent with the initial explanation (e.g., sun’s movement), and as alternative if they were consistent with an alternative explanation of the day/night cycle (e.g., earth’s movement other than the axis rotation), using a set of criteria developed in prior research (Vosniadou & Brewer, 1994). Three scorers marked children’s responses and the reliability was 87%. All disagreements were discussed and the scoring was repeated. Reliability amongst two scorers at the second scoring was 98%.

Children’s responses were scored as 3 (for scientific), 2 (for alternative) and 1 (for initial), and were subjected to a mixed analysis of variance [pre-post test (within subject factor) * grades (between subjects factor) * texts (between subjects factor)] in order to see how the presentation of each text affected children’s explanations at both ages.

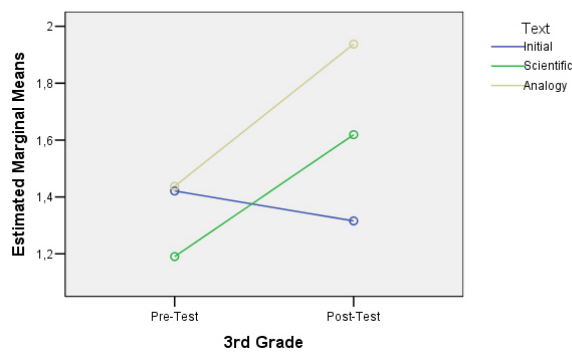


Figure 3: Mean Score of 3rd Graders’ Performance in Pre & Post Test as a Function of Text

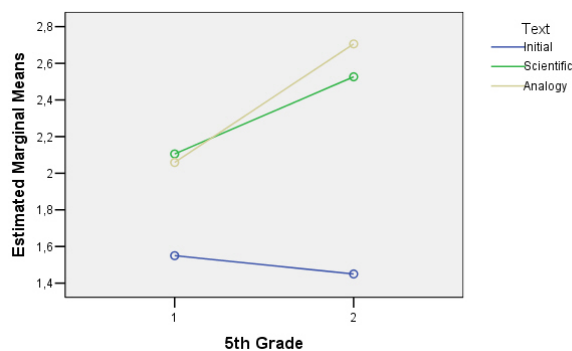


Figure 4: Mean Score of 5th Graders’ Performance in Pre & Post Test as a Function of Text

The results showed statistically main effects for text type [$F(2,106)=12,668, p<.001$] in favor of changes in the explanations of the children in the scientific and analogy texts. The changes in children’s explanations were mostly due to changes in their verbal utterances and not in their drawings.

In an effort to understand in a more global way, exactly how the texts influenced children’s explanations from the pre-test to the post-test, we assigned the children to initial, alternative, unclear scientific, and scientific explanations, on the basis of both their verbal utterances and their drawings. Table 2 shows the results of this analysis for scientific and analogy texts only, as the initial text had no effect on children’s explanations from pre to post-test. The results are in favour of the analogy text but were not statistically significant. As can be seen, most of 3rd graders change from an initial to an alternative model and the changes from alternative to scientific models increase in the 5th grade group. There are some but still very few, ‘radical changes’ from initial to scientific models, observed again in favour of the analogy group.

Table 2: Scientific & Analogy Texts’ Influence in Children’s Change of Explanations on Day/Night Cycle

Change in Explanation	3 rd Grade		5 th Grade	
	Scientific	Analogy	Scientific	Analogy
From Initial to Alternative	33%	31%	16%	24%
From Initial to Scientific	5%	7%	-	6%
Form Alternative to Scientific	-	7%	5%	18%
From Unclear Scientific to Scientific	-	-	5%	12%
Total	38%	45%	26%	60%

Discussion

The results of the present study confirmed our hypothesis that it would be easier to recall information from expository text when this information is consistent with prior knowledge than when it is not. The children in the present study, and particularly the 3rd graders, recalled more idea units from the text which presented an initial explanation of the day/night cycle than the text which presented a scientific explanation. Also as hypothesized, the inclusion of an analogy from a different but highly familiar domain helped all children recall more idea units from the scientific text with analogies as compared to the scientific text without analogies. These results are consistent with previous studies which investigated

the influence of analogy in the comprehension of science text (Brown & Clement, 1989; Chiu & Lin, 2005; Wong, 1993)

Another purpose of the present study was to understand the mechanisms whereby which counter-intuitive information is distorted as well as the specific ways in which analogy helps to prevent these distortions. Preliminary analysis of the distortions included in children's recalls showed that they represented mostly errors in the mapping of the incongruous causal structure of the new, incoming information into the knowledge base (Gentner, 1983). These mapping errors usually happened in the case of the scientific text, but sometimes they also happened in the case of the initial text, since some children in the initial text condition gave explanations of the day/night cycle closer to the scientific one. It appears that children may commit a number of distortions, such as to invert the causal relations, change the causal agent or object, add causal agents (the moon), change the nature or direction of the agent's movement, etc. They also turn causal statements into descriptive or temporal ones or the opposite. The specific nature of the distortion seems to depend on the interaction between the child's existing knowledge and the structure of the new, incoming information.

Analysis of the changes in children's explanations from the pre to the post-test showed that the changes occurred mostly at the verbal level while children's drawings remained the same. This could have been expected since the new information came in only verbally. Nevertheless, this difference caused several incongruities between the same child's verbal explanations and his/her drawings in the post-test. A number of these incongruities had to do with the role of the moon in the day/night cycle. Many children said that the moon is causally implicated in the day/night cycle in the pre-test, but did not mention, or even denied the role of the moon in the post-test (the texts explicitly stated that the moon does not cause day/night), thus showing an influence of the text in their post-test verbal explanations. However, they continued to draw the moon in the night sky in their post test drawings, making it impossible for us to determine what they had actually understood from the texts.

In general the findings of the present study confirm previous findings from our research based on cross-sectional studies that point to small and gradual changes in the knowledge base rather than radical restructurings (Vosniadou & Brewer, 1992; 1994). It appears that learning from text mechanisms are rather conservative, consisting predominantly in adding and/or deleting pieces of information, thus causing local inconsistencies in the knowledge base which need time to be repaired. Analogies certainly play a positive role in this process, as the present results suggest, but more detailed analysis are needed for a deeper understanding of their exact role in terms of mechanisms involved.

Acknowledgement

This work is supported by the project **ANALOGY: Human-The Analogy Making Species**, financed by the FP6 NEST Program of the European Commission. (STREP Contr. 029088)

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