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THE COMPREHENSION OF COMPLEX GRAPHICS: FACILITATING EFFECTS OF TEXT ON INTEGRATION AND INFERENCE-MAKING

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Abstract

The goal of the present research was to investigate the effects on comprehension and inference-making when prior knowledge about a building was manipulated by means of a text. The text presented an expert-like "walk-through" description of the building, as well as exemplars of the eight types of semantic information previously found to be employed in the comprehension of architectural plans. This was motivated by previous research which: 1) found that the nature of the encoding process is related to both specific prior knowledge of the building and to expertise, and 2) suggested that experts' representations of the building included much more 3-dimensional information whereas sub-experts' representations of the building were much more similar to the 2-dimensional plans used to depict the building.

Results indicated that the text had positive effects on specific types of semantic information acquired about the building, and that inferences on this information permitted the development of mental models which included a greater number of 3-dimensional aspects of the building. There were also important findings related to expertise which suggest that the search, pattern-recognition, and inference-making operators applied by novices were different from those applied by experts.

Introduction

This research investigates the nature of the cognitive processes involved in the comprehension of graphic information sources and subsequent inference-making in the domain of architecture. This task is inherently interesting to cognitive science since learning from these symbolic graphic sources is a highly developed and multi-leveled process involving the comprehension of several different types of information about a building, including visual/spatial characteristics as well as conceptual, and semantic information about the building depicted (Gobert, 1989; Gobert & Frederiksen, 1988, 1989).

The method employed in the present study is based on the underlying theory that comprehension is a stratified process in which semantic information from a text or graphic is represented by the learner in several levels. The comprehension process involves both the comprehension of the information source as well as the inferences which the learner makes on this information. The working hypothesis employed is that the semantic processes which are used in the understanding of discourse, i.e., text or language, should also operate in the understanding of graphic information sources. This is not to suggest that there may not be different component processes specific to particular modalities of information, i.e., visual or graphic, rather that there may be some commonality between those for graphics and those for text at certain levels of the comprehension process.

Briefly, this stratified model, as well specified in discourse comprehension (Frederiksen, 1988; vanDijk & Kintsch, 1983) encompasses three levels of representation, 1) syntactic parsing, 2) the encoding of semantic information, and 3) development of a mental model (Johnson-Laird, 1983) or situation model (vanDijk & Kintsch, 1983). My previous work (Gobert & Frederiksen, 1988, 1989) investigated specifically the semantic level of representation of architectural plans via a think aloud task. Using methods of semantic analysis based on a BNF grammar (Backus-

Naur Form; Wirth, 1976), it was determined that there are eight specific types of semantic information required to comprehend a building from its architectural plans, which are: object identity, object description, geometry, function, location, supporting structure, part structure, and circulation/access. Furthermore, it was found that the nature of this encoding process is related to both prior knowledge and to expertise such that the attentional search strategies employed by experts in order to acquire information from the plans resulted in representations of the building which were isomorphic to the building itself as a 3-dimensional entity. Novices, on the other hand, used a "floor by floor" attentional search strategy resulting in representations which were poorer in that they were more similar to the plans used to depict the building.

The present research examines this interaction of expertise and prior knowledge on the acquisition and comprehension of information depicted in architectural graphics and investigates the resulting knowledge representation by means of a number of architecturally relevant tasks.

Method

In order to precisely determine the effects of prior knowledge on knowledge acquisition and comprehension, prior knowledge of the building was manipulated by means of a text which presented an expert-like, "walk-through" description of the chosen building as an example of an expert-like search strategy as well as exemplars of the eight types of semantic information used to interpret plans (Gobert, 1989; Gobert & Frederiksen, 1988, 1989). The text and graphic are not informationally or computationally equivalent (Larkin & Simon, 1987) and are not intended to be; rather, the purpose of the text was to test the efficacy of providing both procedural information regarding search strategies as well as descriptive information about the building specifically on subsequent architecturally relevant tasks.

In order to determine the effects on knowledge acquisition and comprehension which are due to expertise, this study employs a fully crossed design.

Materials

The building which has been chosen as the input for this study is House II by Peter Eisenman (Eisenman, 1982). Of this building, three plans (lower, upper, roof) were provided. Plans depict buildings floor by floor, and although reading of plans provides access to some 3-dimensional information, inferences are required on information presented in the plans in order to represent the building as 3-dimensional. Examples of 2-dimensional information which requires inference-making are: 1) dotted lines suggest that there is an object above which is lower than the ceiling; 2) thick pen weights indicate the location in the building through which the plan has been cut and hence an object which is outlined by a thick pen weight rises through that floor level; and 3) thin pen weights indicate that the object does not rise up completely to the ceiling.

Procedure

Fourty subjects in total participated in this study. The novice group consisted of twenty students in their second year of architecture school at the University of Toronto; and twenty professional architects all with a minimum of ten years experience comprised the expert group.

The text was given to one group <u>before</u> viewing the plans (pre-text), versus a control group. The tasks which were required were: a semantic interpretation task, a comprehension test, and drawing of 2 cross-sections; however, for the purposes of this paper, only the results from the comprehension test and the cross-sections will be discussed.

The comprehension test which was administered immediately after the subjects had given their on-line semantic interpretation of the plans comprised of items evaluating: a) 2-dimensional comprehension, i.e., information which could be directly acquired from the plans; b) 3-dimensional comprehension, i.e., information requiring inference-making beyond the information given in the plans; c) architectural genre, i.e., knowledge from long-term memory about the historical influences of the building's design, etc.; and d) each of the eight semantic categories previously discussed.

The drawing of the cross-sections was requested immediately after the comprehension test was completed. A ten minute time limit was imposed for each of the two drawings. For this task, each cross-section was scored for both its overall characteristics, i.e., spatial layout, and specific characteristics, i.e., presence of features.

Method of Analysis

Manovas were performed using SPSS, as follows:

To assess comprehension of the plans and building:

1) 2-dimensional comprehension, 3-dimensional comprehension, and architectural genre by text condition (pre versus none) and by level of expertise (novices versus experts).

2) comprehension items regarding the eight different semantic categories were analyzed with regard to differences on these types of semantic knowledge due to the text (pre versus none) and to level of expertise (novices versus experts).

To assess the ways in which knowledge was used on an architecturally relevant task:

3) 4 scores, 1 overall and 1 specific for each of the two cross-sections were taken, a multivariate analysis of variance tested the effects due to both text condition (pre versus none) and by level of expertise (novices versus experts).

Results and Discussion

Regarding analysis 1:

There were no statistically significant differences on 2-dimensional comprehension, 3-dimensional comprehension, or architectural genre by text condition or by expertise. Although there was a trend favoring the experts in the pre-text condition for all three measures, this effect was not large enough to reach statistical significance. The conclusion to be made here was that, when subjects were queried regarding these features of the building, they were able to use the knowledge they had in order to generate inferences which allowed them to correctly answer the comprehension questions, regardless of expertise or text group.

Regarding analysis 2: (see table 1 and figure 1):

TABLE 1
Multivariate Analysis for Comprehension: Effects of Text on Semantic Information

Multivariate F = .010 (Wilks)
Univariate F-tests (1,30 df)

Variable	SS	MS	F	sig. of F
Desc. Info.	57.82	12.00	4.82	0.036*
Circ. Info.	8.88	1.15	7.69	0.009*
Struc. Info.	12.37	3.80	3.25	0.081*
Loc. Info.	5.97	8.07	0.74	0.397**

* sig. in multivariate and univariate tests
** sig. in multivariate test only

A significant multivariate effect was found for the pre text condition for four of the eight types of semantic information, suggesting that those in the text condition had acquired more information about the building in terms of its descriptive characteristics, its circulation / access routes, and its supporting structural system, thus the text apparently facilitated the search process through the plans, allowing individuals to acquire more information about the building.

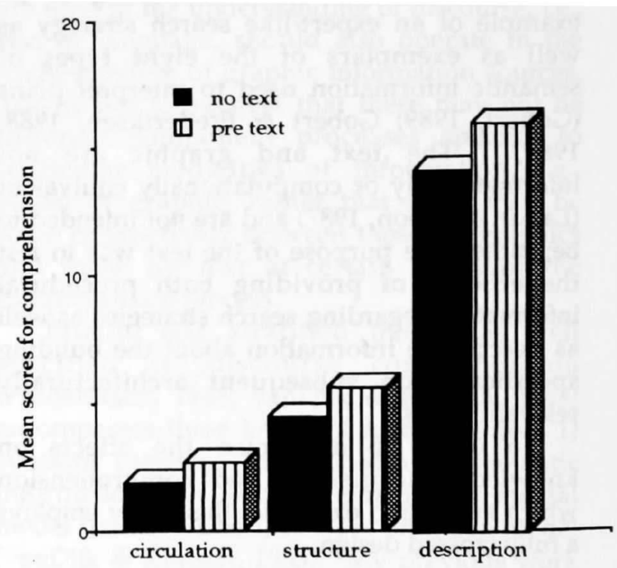

Figure 1: Text effects for comprehension of semantic information

Regarding analysis 3: (see table 2 and figure 2):

TABLE 2
Multivariate Analysis for Cross-Sections: Experts versus Novices

Multivariate F = .000 (Wilks)

<u>Univariate F-tests</u> (1,37 df)

Variable	**SS**	**MS**	**F**	**sig. of F**
<u>section 1:</u>				
overall	15.18	.766	19.82	0.000 *
specific	26.79	4.03	6.66	0.014 *
<u>section 2:</u>				
overall	27.55	.749	36.75	0.000 *
specific	45.52	4.16	10.95	0.002 *

* significant in multivariate and univariate tests

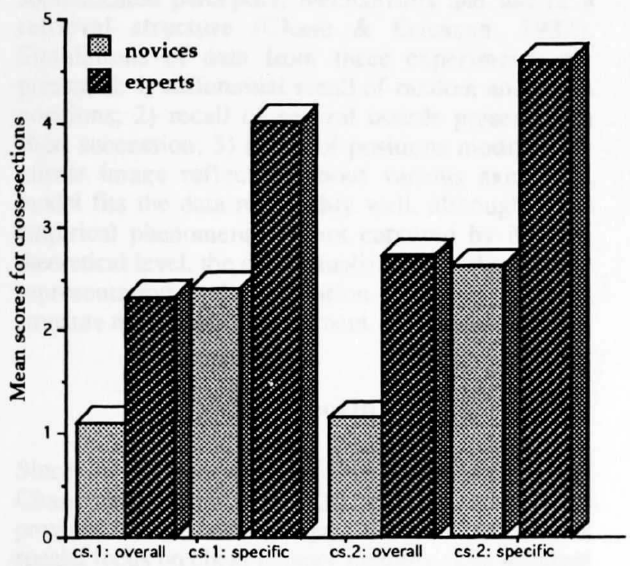

Figure 2: Expertise effects for cross-sections

The most interesting of these effects is that obtained for the cross-sections. A large statistically significant multivariate effect was obtained by the expert group on both scores for both cross-sections. See figure 2. These effects are very interesting in that although there were no significant differences in the content of the knowledge due to text or expertise when probed for 2-dimensional comprehension and 3-dimensional comprehension, these strong effects yielded for the cross-sections suggests that there is a large process difference favoring the experts on a task requiring the transformation of 2-dimensional information into a 3-dimensional depiction. It is further hypothesized that the experts employ inference-making operators on the 2-dimensional information that they acquired from information sources given in order to construct a 3-dimensional representation of the building.

Preliminary analysis of the think aloud data suggests that the large differences observed on the drawing of cross-sections is largely due to the use of search, pattern recognition, and inference-making processes (Larkin & Simon, 1987) which were used by the experts during the knowledge acquisition phase. More specifically, from the protocols which have been analyzed, the knowledge acquisition phase appears to be an iterative process which continues until the learner's mental model is complete, <u>or</u> s/he has reached an impasse. The knowledge acquisition process from the architectural drawings is hypothesized to occur in the following manner. In accordance with the literature on visual perception, it is acknowledged that the search process takes place in two stages (Arbib et al., 1987; Ullman et al.,1988), the first being an effortless, parallel scan of the diagram which in this case, is hypothesized to lead to the classification of a building type, i.e., a Modern building. The second stage of search is goal-directed and serial, in which experts are likely to seek confirmation of their classification of the building as "Modern" by using information from long-term memory to re-direct the search process to seek out specific features of "Modern" buildings, i.e., free-standing walls, columnar structure, rotation around a square grid, and many glass exterior walls. It is hypothesized that this search and knowledge acquisition process takes place in an iterative fashion until comprehension has been acquired on the combinatorial basis of the graphics, knowledge from long-term memory, and inferences made on the two sources of knowledge. For novices, lacking the domain knowledge to either correctly classify the building, or lack the knowledge of its defining characteristics, the search process is much more random, leading to a disjointed mental model. Furthermore, it is hypothesized that the novices also lack the operators upon which 2-dimensional information from the plans is constructed into a model of the building.

Further data analysis of the on-line semantic interpretation data is necessary in order to further delineate the nature of the knowledge acquisition process, as well as to determine differences in strategies which experts and novices employ in comprehending a 3-dimensional building from its plans which are 2-dimensional.

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