Recall of Concepts and Relationships Learned by Conceptual Models: The Impact of Narratives, General-Purpose, and Pattern-based Conceptual Grammars

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Abstract. Conceptual models are the means by which a designer expresses his or her understanding of an envisioned information system. This research investigates whether modeling experts or novices differ in understanding conceptual models represented by textual descriptions in the form of narratives, by general-purpose conceptual modeling languages, such as entity-relationship models or by pattern-based conceptual modeling languages. Cognitive science theories on memory systems are adopted and a cued recall experiment carried out. The experimental results suggest that narratives cannot be underestimated during learning processes in information systems design. Furthermore, general-purpose conceptual modeling languages tend to lack capabilities for supporting template-based learning. The results are differentiated between subjects with at least basic conceptual modeling skills and novices.

Keywords. Conceptual modeling, conceptual patterns, design patterns, entity relationship diagrams, empirical study, knowledge structures, domain understanding, cued recall, template, experts, novices, narratives, chunks

1 Introduction

Conceptual models are complex knowledge structures used by designers to represent integrated collections of concepts and relationships about application domains. The knowledge required to create effective conceptual models fall into two categories: 1) knowledge related to conceptual modeling grammars and associated techniques; and 2) knowledge about the domain being modeled. For knowledge related to conceptual modeling grammars, designers must know basic concepts and abstract modeling techniques, independent of a particular domain. Different types of designers create and use conceptual models, with experts being more likely to conceptualize and understand domain descriptions than novices [1].

In addition, knowledge structures are developed for some domains. For instance, reference models encompass knowledge structures that provide templates for large domains that can be instantiated by design teams. Alexander's well-recognized patterns [2] are smaller knowledge structures that can be used to express domain knowledge. Examples of patterns include place-transaction [3] and service-interaction [18]. Knowledge structures and patterns form larger conceptual groups, are referred to as chunks. Cognitive load theory emphasizes chunking as effective when considering many concepts and relationships simultaneously [4].

The objective of this research is to investigate design patterns as knowledge structures in conceptual modeling. Grouping stimuli by chunks by novices and experts, a recall experiment is carried out in which subjects who use a newly learned conceptual pattern language are compared to a control group. This research investigates two questions for experts vs. novices: (a) Do conceptual patterns improve the creation of a conceptual model? and (b) Do conceptual patterns improve recall of concepts and relationships? This study is part of more general research on shared understanding in design teams.

2 Related Research

Various conceptual modeling languages have been created including simple narrative text, entity-relationship diagrams, star diagrams, formal ontologies, business process models, use case descriptions, and object-oriented representations. Prior research has investigated such as ease of use [5], effectiveness, and efficiency of a conceptual modeling language [6]. Few studies, however, have empirically compared different kinds of conceptual modeling languages (narrative text, entity-relationship diagrams, and semantic patterns).

Understanding conceptual models relies on memory processes, called *chunking,* that enable the collection of pieces of information from conceptual models and merging of them into integrated mental representations [5]. Chunking mechanisms are basic for mental processes used by conceptual modeling. Conceptual models in textual descriptions provide little schematic structures, yet require processing of primitive stimuli. In contrast, conceptual models whose representation is based on generic conceptual grammars, such as Entity-Relationship Diagrams (ERD) [6], provide basic schematic structures, but the more complex conceptual modeling languages need to be learned by the user beforehand. Pattern-based conceptual languages provide higher-order semantic structures that encompass generic domain knowledge and can be reused in conceptual design. Mental representations of conceptual models can be derived by the following three learning processes:

1. Basic stimuli process: derivation of mental representations from unstructured conceptual models, such as textual representations.

2. General model process: derivation of mental representations from structured conceptual models based on general-purpose conceptual grammars, such as entity-relationship diagrams or class diagrams. Domain knowledge is inherently part of a conceptual model.
3. Template-guided model process: mental representations derived from patterns expressed by structured conceptual models with domain knowledge.

In investigations of whether entities and attributes are distinct items in individual's mental representations [7], entity-attribute pairs are related by a "hasAttribute" relationship. In contrast, most application domains include several kinds of relationships. Furthermore, natural language descriptions informally use several kinds of relationships to connect entities. As one moves from natural language descriptions to entity-relationship diagrams to semantic design patterns, the designer implicitly imposes additional structure. It is not clear, however, whether this additional structure leads to a positive effect on individual understanding [6].

This research explores whether an additional structure given by an entity-relationship diagram or a design pattern improves the creation of a conceptual model. An entity-relationship model is compared to a conceptual model created by a pattern language. The expectation is that the additional cognitive effort for deriving a mental representation from an entity-relationship model or from a pattern-based models is compensated for by more sophisticated mental representations [8].

The study uses a cued recall experiment to assess whether concepts and relationships in a conceptual model are: a) correctly remembered or b) incorrectly included in a conceptual model. This assessment was carried out for both novices and experts. Table 1 presents the hypotheses investigated.

Table 1. Hypotheses

	Description with expected outcome
H1a	Subjects will *recall more concepts and relationships* when they are learned via constructing entity-relationship diagrams than when they are learned via reading natural language narratives
H1b	Subjects will *recall more concepts and relationships* when they are learned via semantic patterns than when they are learned via constructing entity-relationship diagrams
H1c	Subjects will *recall more concepts and relationships* when they are learned via semantic patterns than when they are learned via reading natural language narratives
H2a	Subjects will *reject more added concepts and relationships* when they are learned via constructing entity-relationship diagrams than when they are learned via reading natural language narratives
H2b	Subjects will *reject more added concepts and relationships* when they are learned via semantic patterns than when they are learned via constructing entity-relationship diagrams
H2c	Subjects will *reject more added concepts and relationships* when they are learned via semantic patterns than when they are learned via reading natural language narratives
H3a	Subjects will *have less unknown concepts and relationships* when they are learned via constructing entity-relationship diagrams than when they are learned via reading natural language narratives
H3b	Subjects will *have less unknown concepts and relationships* when they are learned via

	semantic patterns than when they are learned via constructing entity-relationship diagrams
H3c	Subjects will *have less unknown concepts and relationships* when they are learned via semantic patterns than when they are learned via reading natural language narratives

3 Research Experiment

Treatments: Three different treatments were used in this study: 1) textual narratives (basic stimuli process); 2) entity-relationship diagrammatic (general model process) [9]; and 3) design patterns (template-guided model process).

Narratives are a natural form for describing situations of intended information systems using textual descriptions [10]. They are small stories that explicitly describe what happens if one or more actors perform in an anticipated manner. More formally, a situation describes which actors interact with one another or with services. Interactions can transfer information objects from one actor to another. An entity-relationship model is intended to adopt a "more natural view that the real world consists of entities and relationships. It incorporates some of the important semantic information about the real world" [9]. Entity-relationship diagrams (ERD) relate two entity sets by one relationship set ([9]. Conceptual design patterns capture larger knowledge structures in a schematic manner. They relate typed entities, such as information objects, roles, interactions, services, and physical objects, and define typed relationships between entities [11]. We use a pattern grammar that has been developed for the domain of human and service-oriented communication [11] (cf. Figure 2). For instance, the role interaction pattern has four typed variables (two roles, one information object, and one service) and one relationship (r(ole)-interacts). The role-interaction patterns represent any situation in which one role (sender) sends a message (information object) to another role (receiver) by using an interface service (e.g., a telephone). This pattern grammar was new to every subject and introduced before the experiment started.

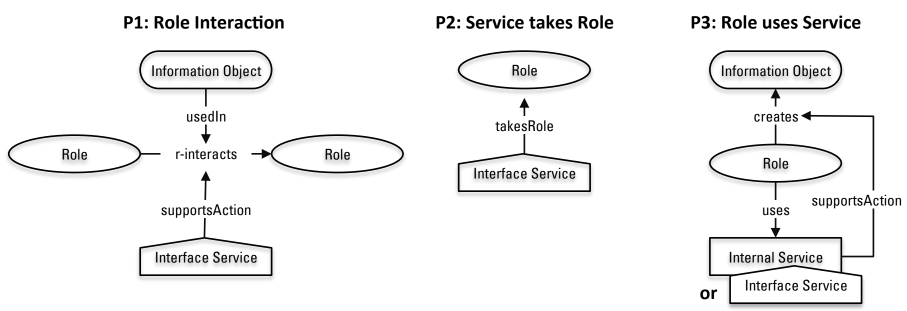

Figure 1. Conceptual design patterns (selection) [11]

Experimental tasks and procedure: each subject was randomly assigned one of the three treatment groups in an online experiment: 0 (narrative), 1 (entity-relationship diagram), and 2 (pattern). Each experiment consisted of a model extraction phase, a distraction phase, and a recall phase. During the extraction phase for group 0, subjects were asked to read the textual description for an intended information system. Group 1 was asked to identify and mark as many entities and relationships as possible. Group 2 received the same instructions as Group 1 and, additionally, asked to identify and mark as many patterns as possible. During the distraction task a video (3 min.) was shown and subjects were asked three questions about this video. During the recall phase, 40 questions posed on whether concepts and relationships were present in the textual description (cf. Appendix). Subjects could answer 'yes,' 'no,' or 'don't know.' Three control questions were asked. At the beginning, group 1 and 2 refreshed their knowledge of ERD and were taught how to apply patterns of this particular grammar.

A total of 57 subjects (24 female and 33 male, age between 20 and 43) from universities and research institutions in Europe, Asia, and North America participated in the online experiment. Forty-two (42) subjects were students and 15 were professionals (referred to as experts). The subjects' backgrounds were from Computer Science (19), Information Sciences and Technology (17), Economics (5), and MIS (3).

4 Results

Overall 51% of all concepts and relationships were either correctly recalled or correctly rejected. 17% were incorrectly recalled or incorrectly accepted, although subjects could not decide on 32% of all concepts and relationships. Table 2 presents the descriptive statistics.

Table 2. Descriptive statistics ('0': group narratives, '1': group ERD, and '2': group pattern)

Groups		N	Mean	Std.Dev.	Std.Error
Correct concepts	0	13	6.38	2.142	.594
	1	15	4.80	2.210	.571
	2	14	5.93	2.556	.683
Correct Relationships	0	13	7.15	1.625	.451
	1	15	4.8ß	2.145	.554
	2	14	5.36	2.951	.789
Added Concepts	0	13	2.54	1.984	.550
	1	15	2.27	2.052	.530
	2	14	2.57	3.031	.810
Added Relationships	0	13	2.31	1.494	.414
	1	15	2.07	2.120	.547
	2	14	2.21	2.778	.743

Because of non-normality characteristics of all distributions found by our study, the non-parametric Kruskal-Wallis rank sum test was applied [12]. For differences between all three groups, the test became highly significant. However, the dyadic Kruskal-Wallis tests between two groups are only significant for incorrectly identified concepts and relationships. Therefore, we restricted our further analysis to subjects with basic skills (>3 on a 6 point scale) (n=29). For this subset, all three rank sum tests are significant on a 10% significance level due to small sample size. Based on the Wilcoxon rank sum H1b and H3b are accepted whereas H1a and H2c are rejected. The other hypotheses are not significant.

Table 3. Median values for groups and correct, incorrect and unknown items

	Median values for groups		
	0	1	2
Correct (0..2)	27	20.5	23
Incorrect (0..2)	3.5	7	9
Unknown (0..2)	10.5	17	8

5 Discussion

This research has investigated how two different types of conceptual modeling languages contribute to learning and recall. An underlying assumption was that, the more structured a conceptual language, the better the mental representations and, hence, the learning and recall results. However, the results suggest that natural language alone (here, written narratives) is much better suited to learning and recall than expected. Narratives are significantly more effective than general-purpose conceptual modeling languages with respect to recall of concepts and relationships. Pattern-based languages are not more effective than narratives. Pattern-based models more effectively support recall of correct items than general-purpose models. Stories told by narratives resemble those of patterns, supporting our initial assumption that patterns are useful for template-based cognitive processes. The research results indicate that general-purpose languages, such as ERD, provide less support for activating cognitive templates.

For incorrectly recalled items, narratives were even more efficient than pattern-based models. This result poses the question of whether pattern-based models result in expanding mental representations that add complementary items missing in the original description. Pattern-based models performed significantly better than general-purpose languages. This is surprising for a subgroup that has at least basic conceptual modeling skills with entity-relationship diagrams. Again, narratives appear to be at least as good as general-purpose models or pattern-based models.

Several results emerge. First, narratives are a very effective means for supporting cognitive learning processes and building mental representations about information systems. Narratives even exceed capabilities of conceptual models build by more structured conceptual grammars. Because structured conceptual models are necessary for building information systems, it can be concluded that narratives are substantial enhancements for learning processes and building mental representations.

Other research suggests that general-purpose grammars perform better on recall accuracy, whereas narratives and design patterns are expected to be less effective [13]. This research, however, found support for the competing assumption that pattern-based grammars, such as the one used in this study, exhibit improved learning processes. All of these results were found for subjects with at least basic conceptual modeling skills. Novices were not able to use structures and pattern codes provided by conceptual grammars.

6 Conclusion

This research has investigated whether learning processes are better supported by conceptual models based on general-purpose grammars or pattern-based grammars compared to natural language narratives. A cued recall experiment found evidence of significant differences between general-purpose grammars and pattern-based grammars with respect to correct and unknown items. Narratives provided efficient support for learning processes in the design of information systems. This study also showed that differences between novices and skilled modelers should be accommodated. Finally, theories from cognitive science, in particular memory theories, guided the study. This research is an initial attempt to obtain an understanding of cognitive processes and mental representations related to conceptual modeling.

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Appendix: Questionnaire [Abbreviated]

C: concept. R: relationship, y: part of descriptions, e: extra entity (concept / relationship)

Ease of Use Modeling with a Particular CML (EoU-CML)
- Learning to use Entity-Relationship Diagrams (ERD) was easy for me
- Modeling with ERD is clear and understandable

Ease of Use Modeling with a Particular CML (EoU-CML)
- Learning to use Pre-Artifact Patterns (PAP) was easy for me
- Modeling with PAP is clear and understandable

Correct Concepts / Relationships [9]
- Mr. Jones is relationship manager [C][y]
- Mr. Jones manages financial portfolios [C][y]

Correct Concepts / Relationships [Total: 10]
- Total assets are discussed [C][y]
- Mr. Jones is adding todos [R][y]

Extra Concepts / Rels [Total: 10]
- Mr. Jones is a bank assistent [C][e]
- Mr. Jones manages family offices for clients [C][e]

Extra Concepts / Rels [Total: 10]
- Total assets are visualized [C][e]
- Mr. Jones assigns todos to his assistant [R][e]

Questionnaire: User Satisfaction with CM Understanding
- I am very ***content*** with my understanding of the requirements given by the narratives
- I am very ***pleased*** with my understanding of the requirements given by the narratives
- Overall, I am very ***satisfied*** with my understanding of the requirements given by the narratives

Questionnaire: User Satisfaction with CM Understanding [analogously]