How do we acquire understanding of conceptual models?

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ABSTRACT

In organizations, conceptual models are used for understanding the domain concepts. Such models are crucial in analysis and development of information systems. An important factor of using the conceptual models is how quickly analysts are able to learn the domain concepts as depicted in the models. Using a laboratory experiment, this research used eye tracking technique to capture the speed of acquisition of understanding conceptual models. Two sets of conceptual models were used in this study- one theory based (REA pattern) and the other non-theory based (non REA pattern). It was found that the rate of learning of the domain concepts was faster with theory based models than with non-theory based models. However, users of the non-theory based model were able to catch up with the learning of the model concepts after being repeatedly exposed to the model.

Keywords

REA pattern, Conceptual Modeling Learning, Eye Tracking

INTRODUCTION

Conceptual models are visual representations of domains developed for identifying the requirements for software development (Gemino & Wand, 2005). These models are intended to facilitate communications between organizational stakeholders and serve as a basis for systems analysis and design (Hoffer, Prescott, & McFadden, 2007). Users perform various analytical tasks based on understanding of the conceptual models. An important factor of using conceptual models is how quickly users understand these models to perform tasks. Using eye tracking technology, this research focuses on to identify the s*peed of acquiring conceptual model understanding*. By using two versions of the same conceptual model, this research aims at identifying whether a particular version of conceptual model expedite understanding as compared to the other one. By investigating the process of how users acquire understanding of conceptual models, appropriate versions of conceptual models can be suggested to be used in practice.

In literature, several types of conceptual models are described such as ontologically sound and non-ontological based (those that violate ontological principles). In terms of learning, do some conceptual models (such as ontological) *expedite* learning domain concepts? And importantly, does the difference between ontological and non-ontological models fade away as users become more familiar with the models?

This research explores these questions with the help of an eye tracking study. In the next section, the conceptual model –REA pattern is discussed. This is followed by the theory, hypotheses, and experimental setup of the study. The final two sections are initial results and conclusion.

REA PATTERN

The focus of the conceptual models is to understand the domain concepts and is therefore often used in the organizations (Wand & Weber., 1993). This research focuses on a conceptual model termed *Resource, Event, and Agent* (REA) pattern (McCarthy, 1982) which is commonly used in the accounting domain. REA pattern is selected as it directly relates to organizing domain concepts in a structured way and it has been tested and used empirically in the context of developing and using conceptual models (Fuller, Murthy, & Schafer, 2010; Gerard, 2005). The REA pattern emphasizes that agents perform events to improve their state. The domain that is conceptualized can broadly be described as business, where particular situations of interest (e.g. transactions) are characterized by the presence of dual 'give' and 'take' events.

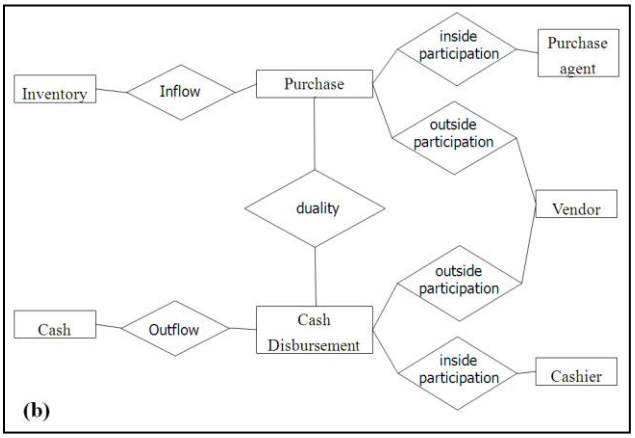

Figure 1. Example of REA pattern

To provide an example of a REA pattern consider the situation where a factory wishes to produce finished goods that can be sold to generate revenue. For this purpose it has to use and consume resources such as raw materials. The emphasis on dual 'give' and 'take' events to describe business situations can be related to the accounting domain. Figure 1 above shows a REA pattern of an acquisition/payment process of a retail company. In this Figure, the resources (inventory and cash), events (purchase and cash disbursement), and agents (purchase, vendor, and cashier) are organized from left to right. When this arrangement of REA objects is violated, the resultant diagram is termed *non-REA pattern*.

To explain the difference between REA and Non REA pattern, consider Figure 2 where the patterns are presented. The concepts in both patterns are the same but they are arranged differently. In the REA pattern, the concepts are organized left to right in terms of Resources, Events, and Agents. In the non-REA pattern, the concepts are mixed up without following any particular order.

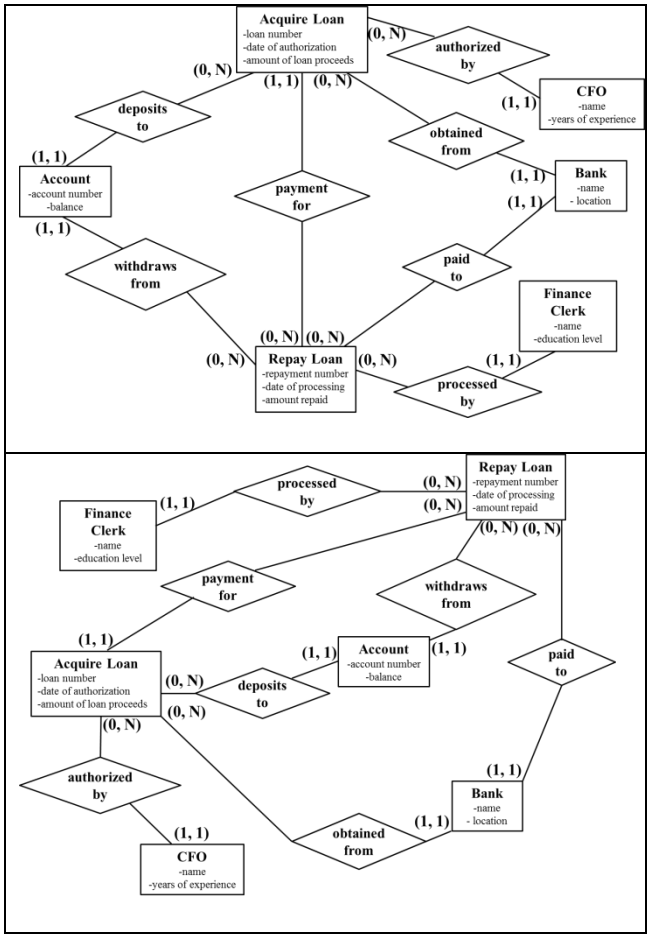

Figure 2. Example of REA & non-REA patterns

A common arrangement in a REA pattern layout is one where resources, events, and agents are positioned in left, central, and right columns respectively on the diagram. The same layout conventions can be found in examples of debt and financing (see Figure 1 of Poels, 2011). Poels (2011) and Poels et al. (2011) have explored this issue further and explained it from the perspective of pattern recognition theories. Modelers that have knowledge structures in accordance with the REA pattern can recognize resource-event-agent structures in conceptual models developed using the REA pattern, and this recognition eases understanding of the models. Poels et al. (2011) also found out that if model users are not familiar with the REA concepts then their performance is significantly less than REA pattern trained users. This indicates that to reap the benefits of the REA pattern for conceptual modeling, a minimum level of familiarity with the REA concepts is required.

Although there are many ways of creating ontological and non-ontological versions of conceptual models but REA possesses certain advantages over other conceptual models[1]. The main advantage being a rearrangement of the concepts in the REA pattern can generate non-REA pattern without changing any concepts of the models (thus both models are informationally equivalent).

THEORY

The theory stems from the work on multimedia learning in which a common problem is that individuals are faced with a learning task that demands more from their cognitive resources (such as working memory) than they can sustain - a situation known as *cognitive overload* (Mayer & Moreno, 2003). Mayer and Moreno (2003) suggests that several methods can be used to reduce cognitive overload in learning situations, an important one being *signaling*. In signaling, visual cues (such as organization of concepts) are provided to learners to reduce their cognitive load by helping them to select, organize, and process relevant information. This method helps in the process of selecting and organizing relevant information. Recent research (Poels, 2011) has demonstrated that the REA pattern may help in understanding conceptual models because it provides visual cues that help in identifying resources, events, agents, and their relationships. Based on cognitive learning theory (Mayer, 2001), it is predicted that when the business domain concepts are organized in REA pattern then it facilitates understanding. The speed of understanding may be hampered when non REA pattern is used.

Mayer (1989) suggests that if people are trained to learn a domain explicitly through objects, actions, and their

[1] In some conceptual models, the non-ontological version differs significantly from the ontological version (e.g. use of optional Vs mandatory properties in ER). We do not use such models as there may be some long term benefit of using ontological models as they have additional domain concepts modeled which are not modeled in non-ontological models. In contrast, the two versions of REA models differ only in the way the models are reorganized.

relationships, then they learn the domain faster. Accordingly it is proposed that compared to non-REA pattern, a viewer is able to understand the business transactions faster when these transactions are shown in REA pattern. Because of cognitive overload, it can also be predicted that the viewers of REA pattern will perform better in tasks related to the model as compared to the viewers of non-REA pattern. However, if non-REA patterns are exposed to viewers repeatedly then there is no longer a cognitive overload faced by these readers. Thus, the difference between the two groups in terms of task performance and speed of learning will diminish when the models are exposed repeatedly. To test these propositions, an eye tracking study was conducted.

Eye tracking offers a window into how individuals read and scan information that is displayed to them (Rayner 1998). Although eye-tracking technology has been used for over 30 years, the technology was unreliable and data interpretation was time consuming (Collewijn, 1999). Over the years, the technology has become more reliable, user friendly, and affordable (Jacob & Karn, 2003) and thus suitable for analyzing mental processes of users. Using eye tracking it is possible to identify how much time a user has spent on a specific area of a diagram and how quickly a viewer views a particular area. Thus it is possible to compare the speed of domain understanding between two models: REA and non-REA patterns. During understanding tasks where users view information relevant to the decision, eye movements provide a valid measure of distribution of attention (Glaholt & Reingold, 2011). By relating eye movements with decision making data, one can obtain a picture of the decision making process.

Two common eye movement metrics are: eye fixations and eye saccades (Sharif & Maletic, 2010). Eye movements are made up of short bursts of stationary visual display termed *fixations* and are filled up with rapid and continuous movements termed *saccades* (Jacob, 1995). During fixations, eyes remain almost motionless, whereas saccades are movements from one fixation to another. A typical fixation lasts approximately 200-300 milliseconds and is generally understood to indicate where viewer's attention is directed (Rayner, 1998). When eyes fixate on a certain area, the brain starts to process the visual information received from the eyes (Rayner, 1998). For this research, a relevant eye tracking metric is the *"time for first fixation."* This metric indicates how quickly a user converges his/her eyes on a specific area of interest.

HYPOTHESES

Based on the difference in cognitive overload between the two groups- REA pattern and non-REA pattern, H1 is proposed.

H1: Users of the REA pattern will be *more accurate* in answering questions on business transactions depicted in the REA model than those who are provided with non REA pattern.

Time for first fixation is expected to be low for those viewing REA pattern and answering a task as the concepts that users are looking for are well organized. Therefore, it will take less effort to remember the position of these concepts than those who will use non REA pattern. Accordingly the next hypothesis of this research is:

H2: users of the REA pattern will have *faster "time for first fixation"* on concepts depicted on business transaction tasks compared to the users of the non REA pattern.

The internal representations of users get affected by being exposed to an engaging task with the model (Shaft & Vessey, 2006). Thus when users get exposed repeatedly with engaging tasks related to a model, this exposure modifies the internal representation of the conceptual model in user's mind. As the internal representation gets modified, users are able to learn the model better and perform the tasks faster and more accurately. This means that at a certain point of time after being exposed to the non REA pattern, the cognitive overload of the non REA pattern viewers are expected to be low.

H3: The difference in task performance and time for first fixation on concepts depicted on business transactions *will fade away* between the two groups when both groups are repeatedly exposed to the REA models.

EXPERIMENTAL SETUP

To test the hypotheses, a laboratory study was conducted with business graduate students from a US university. The study had 1X 2 between design where subjects were randomly assigned to one of the groups: REA pattern and non-REA pattern. 44 students (22 in each group) as subjects who enrolled in the business analytics course participated in this study. The subjects were chosen as they learnt the basic concepts of data modeling similar to REA pattern in business analytics course. Thus when the subjects are provided with REA or Non REA pattern, they were able to understand the semantics of the model. As previous research (Poels, 2011) indicated that minimum familiarity of REA concepts are required to get the benefits of REA pattern therefore the subjects were introduced to the concepts of REA (Resource, Events, and Agents) but not shown the REA pattern. For participation, subjects received 1.5% course grade. The REA pattern and non-REA pattern as shown in Figure 2 were used in this study. Same domain concepts were covered in both REA models.

Each subject was placed in front of a computer fitted with an eye tracker Tobii X2 60. At first, subjects' eyes were calibrated and validated (a standard procedure for eye tracking) by asking them to follow a series of dots in the screen. After this procedure, the subjects accessed a web based questionnaire to fill up their background domain

and modeling knowledge. Following this, subjects were shown a question based on the REA model (Appendix A) and then the model depending on the group they belonged to. Once the subjects viewed the model carefully, they clicked on to the next screen to answer the question. Subjects could click the back button to view the model again in order to answer the question. Examples of such questions are a) is it possible to acquire a loan from places other than a bank? and b) does a finance clerk process a loan repayment to a bank? These questions can be considered as problem solving questions as answering them requires deep level of engagement of viewers.

To ensure that subjects are adequately exposed to the model, a series of twenty questions were asked to the subjects. This means that subjects were exposed to the model twenty times as described above. The answers to the questions (Yes/No) were recorded through the website and the eye data were recorded in the Tobii software.

INITIAL RESULTS

Prior to conducting the main study, a pilot study was conducted with 5 PhD students who are knowledgeable about REA concepts. Based on their feedback, some questions were modified for the study. Two types of analysis are done in this study- one with the performance of the task and the other the eye movement data for answering each task. The percentage of correct answer for each task was calculated and compared between the two groups (Table 1).

Question	Non-REA	REA	Question	Non-REA	REA
Q1	0.73	0.86	Q11	0.82	0.86
Q2	0.82	0.86	Q12	0.82	0.86
Q3	0.77	0.86	Q13	0.82	0.86
Q4	0.82	0.86	Q14	0.86	0.86
Q5	0.77	0.86	Q15	0.86	0.86
Q6	0.82	0.91	Q16	0.82	0.86
Q7	0.82	0.86	Q17	0.91	0.91
Q8	0.86	0.86	Q18	0.86	0.91
Q9	0.86	0.91	Q19	0.91	0.91
Q10	0.86	0.86	Q20	0.86	0.86

Table 1. Percentage of correct answers

The data shows that the percentage of correct answers gradually improved for the non-REA pattern group whereas the percentage of correct answers remained steady for the REA pattern group. The performance difference between the two groups can be visually seen in Figure 3 below.

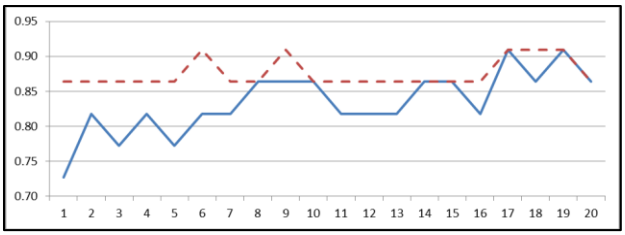

Figure 3. Comparison of task performance between REA pattern (solid line) and non-REA pattern (dotted line)

It is interesting to note that the gap between the two groups reduced gradually and the performance remained almost the same during the answering of the last four questions. Further t-test analysis will confirm this proposition.

To perform time for first fixation analysis, areas of interests (AOI) were identified from the REA model based on the questions. A list of AOI's and the questions are provided in Appendix A. For example, to answer the question "is it possible to acquire a loan from places other than a bank?", a subject needs to refer to the entities "Acquire loan" and "Bank." The time it takes to obtain the first fixations in these areas are obtained. The AOIs were drawn around the entities including the cardinalities as these cardinalities were also used to answer the questions. The size of the AOIs was same in both REA pattern and non-pattern. The time for first fixation was analyzed for each subject and compared between the groups. The data is visually shown in Figure 4.

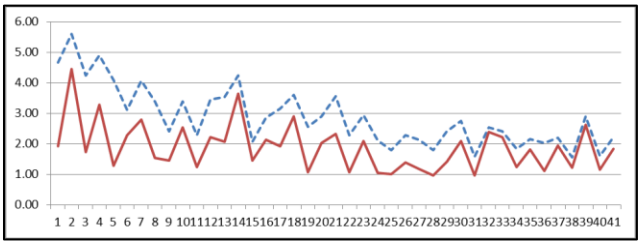

Figure 4: Comparison of time for first fixation between REA pattern (solid line) and non-REA pattern (dotted line)

Each question has two AOIs (except the 20th question which has 3 AOIs). The AOIs for each question and their numbers are listed in Appendix A. To understand this figure, consider the first two AOIs -"Acquire loan" and "Bank" for the first question. These two AOI's are represented as 1 and 2 respectively in X axis. For the REA pattern group, the average time for first fixation for "Acquire loan" and "Bank" were 1.92 seconds and 4.46 seconds respectively. For the non-REA pattern group these numbers were 4.66 seconds and 5.61 seconds respectively.

It is found that the time for first fixations on AOI's related to the tasks were lower for those in the REA pattern group than those in the non-REA pattern group. However, the

gap between the two groups narrowed down over the questions.

The initial analysis on task performance and time for first fixation indicate that learning occurred for both groups as they encountered the questions. However, the learning occurred at a faster rate for the non-REA pattern group as the difference in the task performance and the time for first fixation between the two groups decreased gradually as subjects answered the questions. Further statistical tests need to be done to substantiate this claim and to test the hypotheses 1 to 3. In particular, further analysis should be done on the performance of the questions that were answered at the beginning and then compared with the questions that were answered towards the end. In addition to these analyses, total time for fixation for answering each question and mouse count click analysis need to be done. Mouse count click on back button to view the model again can help to substantiate learning from the model. It is expected that subjects (especially in the non-REA group) will press the back button to view the model several times to answer the initial questions.

To visually support the findings of the time for first fixation, heat maps are provided in Appendix B. These maps suggest that as subjects answered more number of questions, they were able to focus on the areas that were necessary to answer the questions. Compared to the non-REA group, the REA group focused on the specific areas related to AOIs.

CONCLUSION

The first contribution of this study is the use of eye tracking technique to investigate domain understanding. Use of such technique to understand how users acquire domain understanding is novel in approach. The second important contribution of this study is it helps validate the usefulness of REA patterns. REA patterns have been used over 30 years and it has been assumed that there is a cognitive advantage of using this pattern over non-REA pattern (Fuller et al., 2010). This study validates this assumption. The third important contribution of this research is it helps to answer the question that the structure of REA pattern does facilitate the speed of learning domain concepts. Thus REA pattern has a distinct advantage over non-REA pattern in terms of learning domain concepts. This research also demonstrates that once viewers are familiarized with the conceptual model by getting exposed to the model then the difference between REA and non-REA pattern does not matter. This is an important finding as in practice non-theory based models are frequently used.

To extend this research, other types of conceptual models should be used and tested. One particular way to extend this research is to study the effect of providing feedback to the task performance. Modified versions of cognitive task fit model (Shaft & Vessey, 2006) use the concept of feedback of problem solving tasks and performance to modify the internal representation of the problem domain. User's internal representation gets affected by providing feedback of the task performance with the model. Thus it can be predicted that learning from conceptual models can be accelerated if users are provided feedback on their task performance. A follow up study is planned to test this proposition.

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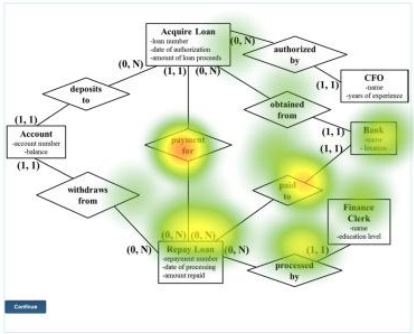
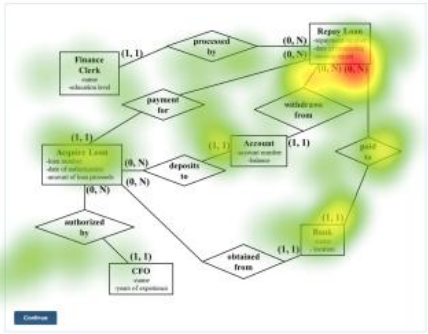
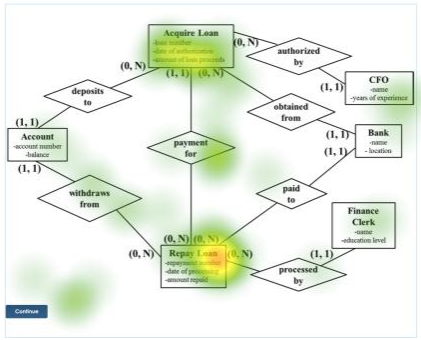
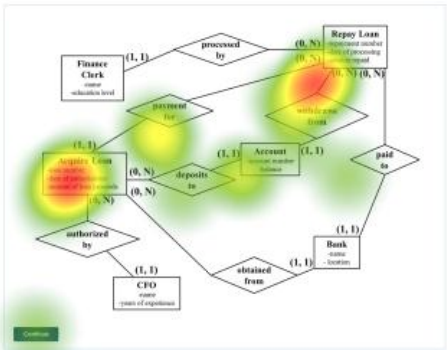
Appendix A: List of performance based tasks

No	Question	AOIs (number)
1	Is it possible to acquire a loan from places other than a bank?	Acquire loan (1), Bank (2)
2	Does a finance clerk process a loan repayment to a bank?	Repay loan (3), Finance Clerk (4)
3	Is loan acquisition processed by a finance clerk?	Acquire loan (5), Finance Clerk (6)
4	Does a CFO authorize a loan repayment?	CFO (7), Repay loan (8)
5	Is a loan repayment paid to a bank?	Repay Loan (9), Bank (10)
6	Is it possible to acquire a loan without the authorization of a CFO?	Acquire loan (11), CFO (12)
7	Are the loan proceeds deposited to a specific account?	Acquire loan (13), Account (14)
8	Can a bank be associated with no loan repayment?	Repay loan (15), Bank (16)
9	Is it possible to deposit a specific loan proceed to more than one account?	Acquire loan (17), Account (18)
10	Can a bank be associated with no loan acquisition?	Bank (19), Acquire Loan (20)
11	Is it possible to trace the total amount of loan repayments for a loan with loan number?	Acquire loan (21), Repay loan (22)
12	Is it possible to repay a loan over a period of time?	Acquire loan (23), Repay loan (24)
13	Is it possible to repay a loan other than by using funds from an account?	Repay loan (25), Account (26)
14	Can an account be associated with no loan repayment?	Repay loan (27), Account (28)
15	Is it possible to obtain more than one loan from the same bank?	Acquire loan (29), Bank (30)
16	For a specific loan repayment, is it possible to withdraw funds from more than one account?	Repay loan (31), Account (32)
17	Can an account be associated with no loan acquisition?	Acquire loan (33), Account (34)
18	Can a CFO authorize more than one loan acquisition?	Acquire loan (35), CFO (36)
19	Can a specific repayment number have more than one loan number?	Acquire loan (37), Repay loan (38)
20	Is it possible to repay a loan using funds from an account that was also used to deposit the loan proceeds?	Acquire loan (39), Repay loan (40), Account (41)

Appendix B: Sample Heat maps

Question	REA Group	Non REA Group
5		
12		
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