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WORKING PAPER

User Attitudes towards Pattern-Based Enterprise Information Models: A Replicated Experiment with REA Diagrams

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Abstract. This paper presents a study evaluating the REA-patterns-based approach to enterprise information modelling. We replicated an earlier experiment demonstrating that business students perform a comprehension task more accurately when they recognize REA pattern occurrences in entity-relationship diagrams and that they perceive such diagrams as easier to use than informationally equivalent diagrams with no apparent REA pattern occurrences. These findings were confirmed in the replication, but contrary to the original experiment also efficiency gains in terms of faster understanding were demonstrated. Furthermore, the original experiment was extended by testing a more complete model of user attitudes. It was shown that, after completing the comprehension task, students perceived diagrams with REA pattern occurrences as easier to interpret and more useful, and were more satisfied with them. But somewhat surprisingly, students also perceived such diagrams as more semantically expressive, even if they were informationally equivalent to the control diagrams. It was further shown that perceived semantic expressiveness is related to perceived usefulness, but not to perceived ease of interpretation. The effect of perceived semantic expressiveness on user information satisfaction is not direct, but mediated by perceived usefulness.

Keywords. REA, patterns, modelling, user performance, user attitudes

1. Introduction

The recently proposed pattern-based approach to enterprise information modelling, by Dunn *et al.* (2005), provides a comprehensive and coherent framework for modelling enterprises at various levels of abstraction, including value system, value chain, and business process levels. Its foundation in strategic concepts, such as Porter's Value Chain (Porter, 1985), and basic accounting principles holds great promises for educating business students in the organization of business flows throughout and across enterprises, accounting database modelling, and enterprise systems design. The approach relies heavily on the constructs and models of the REA enterprise domain ontology (Geerts and McCarthy, 2002), which is itself based on the REA accounting data model of McCarthy (1982). This domain ontology is "a semantic theory of how an information system that tracks economic phenomena should be structured in a shared use environment without regard for ever changing technology platforms" (Dunn and McCarthy, 1997, p. 40).

The REA ontology has proven its value in practice, providing a basis for major transaction standards, system interoperability frameworks, and associated business process modelling and analysis methodologies for realizing e-commerce systems, such as ebXML (electronic business using eXtensible Markup Language), ECIMF (E-Commerce Integration Meta-Framework), and UMM (UN/CEFACT Modelling Methodology) (Bergholtz *et al.*, 2003; ECIMF Project Group, 2003). Since its original conception in the early eighties it has been applied or augmented with newer information technologies and methodologies such as Object Orientation (Murthy and Wiggins, 2004), model-driven development (Ellegaard Borch *et al.*, 2003), and XML-based system architectures (Geerts, 2004). But what makes it especially useful as a foundation for enterprise information modelling is its process-orientation, which is a feature shared with ERP-based enterprise systems (McCarthy, 2003). McCarthy (2004) further observes that high end enterprise systems (i.e. those focused towards e-collaboration) increasingly tend to mirror the patterns of the REA ontology; an observation partially supported by O'Leary (2004) in his comparison of the REA ontology and SAP's data model.

A pattern-based approach to modelling presents modelling structures that occur frequently in practice, and prescribes guidelines on how to recognize these structures (Batra and Wishart, 2004). Patterns foster the reuse of existing solutions (Johannesson and Wohed, 1999) and in general avoid "having to reinvent the wheel every time you design or evaluate a new enterprise system" (Dunn *et al.*, 2005, p. 23). Patterns should also help training novice modellers, offering them templates to start with (Batra and Wang, 2004).

Although the benefits of an enterprise information modelling approach promoting the use of patterns seem obvious, in particular when based on a well-defined enterprise domain ontology firmly rooted in accounting and economic theory, there is a lack of research demonstrating and explaining such benefits (Irwin, 2002; Batra, 2005). Moreover, prior research did not always prove the superiority of a pattern-based approach. Batra and Wishart (2004) for instance found that novice modellers tend to overuse some of the offered pattern templates and fit them to the problem at hand, and could not recognize instances of other (more suitable) patterns they learned.

This opens up interesting questions with respect to Dunn *et al.*'s REA-patterns-based approach: Does it really help business students working with enterprise information models? And, how do business students perceive such pattern-based models?

1.1. Related Work

Empirical research in REA-based semantically modelled accounting systems is scarce, as evidenced by the review of Dunn and Grabski (2002). There are a couple of studies that support claims about the benefits of the REA model. Dunn and Grabski (2001) showed better information retrieval performance by accounting users working with an enterprise system based on the REA model than with a system based on the Debit-Credit-Account (DCA) model. In a related study, Dunn and Grabski (2000) demonstrated also that users perceive an REA-based system as more semantically expressive[2] than an informationally equivalent[3] DCA-based system, and that higher perceived semantic expressiveness is associated with higher task accuracy in information retrieval. Gerard (1998) showed that students possessing knowledge structures consistent with REA's transaction pattern (as obtained through training) could design more accurate conceptual accounting databases than students with less consistent knowledge structures.

Whereas these experiments investigated the REA model at the system design or implementation level, other research was conducted at the conceptual modelling level (or 'symbol' level according to David *et al.*'s (1999) research pyramid for Accounting Information Systems (AIS) research). For instance, Gerard (1998) also demonstrated that students with experience in REA conceptual modelling performed better in diagram recall tests and were more able to aggregate attributes into entities than inexperienced students. Dunn and Gerard (2001) observed greater efficiency in information retrieval tasks when REA pattern occurrences were shown in a diagrammatic form than in a textual form. Dunn *et al.* (2003) further showed that users can better identify cardinality errors if presented a set of simple diagrams (showing a single relationship between two entities) than one comprehensive diagram.

Recently, some conceptual modelling level studies directly evaluated the REA model against alternatives. Akoka and Comyn-Wattiau (2004) compared the REA model against DREAM, an object-oriented model for multi-dimensional accounting information systems, and concluded that DREAM was more semantically expressive, but also more complex than REA. As their study was theoretical, the impact of these

[2] The ability to express everything that needs to be modelled without much effort from the modeller (Lindland *et al.*, 1994).

differences on conceptual schema users was not investigated. Further, Poels (2003) describes an experiment where business students could more accurately answer comprehension questions about a business process modelled if an entity-relationship diagram is used that shows an REA transaction pattern occurrence (as compared to an informationally equivalent diagram that hides this pattern). In a similar experiment, Poels *et al.* (2004a) could also demonstrate that business students perceive such an entity-relationship diagram as easier to use for conceptual schema validation tasks.

1.2. Research Questions and Goals

The previously sketched state-of-the-art in empirical REA research, especially the experiments by Gerard (1998), and Poels and colleagues (Poels, 2003; Poels *et al.*, 2004a), provide some evidence of the value of an REA-patterns-based approach to enterprise information modelling, in particular within an AIS educational context. Nevertheless, a number of issues remain unresolved. For instance, contrary to expectations, the experiments by Poels and colleagues could not show that the use of REA patterns leads to efficiency gains in understanding (i.e. acquiring business process knowledge faster).[4] Neither was it demonstrated that the use of patterns increases user satisfaction when performing conceptual schema validation tasks. In general, the previous studies are of a preliminary and fragmentary nature, and their results need further validation. A first goal of this paper is therefore to replicate the experiment of Poels *et al.* (2004a), making minor changes to the experiment's design and seeking to confirm (or disconfirm) the obtained results.

A second goal of this paper is to extend our current knowledge of REA-patterns-based conceptual modelling by elaborating and testing a more complete model of user attitudes. We do so by introducing perceived semantic expressiveness (already investigated by Dunn and Grabski (2000) at the system implementation level) as another study variable. If users perform better (more accurate, faster) with entity-relationship diagrams showing REA pattern occurrences, then it is plausible that they perceive such diagrams as easier to use and more useful (and perhaps being more satisfied with them). But users might also perceive

[3] Two diagrams are informationally equivalent if the transformation from one to the other entails no loss of information, i.e. each can be constructed from the other (Siau, 2004).

such diagrams as being more semantically correct and complete than diagrams without apparent REA pattern occurrences (even if 'objectively' the diagrams are informationally equivalent). We therefore investigate if the use of REA patterns in business process modelling has an impact on perceived semantic expressiveness and if this perception is related to other user attitudes such as perceived ease of use, perceived usefulness, and user satisfaction.

Dunn and Grabski (2000) have suggested the investigation of the relationship between perceived semantic expressiveness and perception- and behaviour-based variables of REA-based system (here model) usage. If a model is perceived as more semantically expressive, then users "can more easily refer back to the "reality" of the situation to verify that they are performing the task correctly" (Dunn and Grabski, 2000, p. 81). Hence, the users' perception of how well the model helps understanding the underlying reality might determine their attitude towards the use of patterns. As such, perceived semantic expressiveness would become an important variable to evaluate the success of a pattern-based modelling approach, in casu an REA ontology-based approach.

The rest of this paper is structured as follows: Section 2 presents our research framework and the hypotheses derived from it. In section 3 our research method (i.e. experiment design and operation) is described. Section 4 contains the statistical analysis of the collected data. Finally, section 5 discusses the obtained results and outlines future research directions.

2. Research Framework and Hypotheses

The framework for addressing the research questions is based on Dunn and Grabski's (2002) research model for investigating the factors that affect the performance of model users (Figure 1). According to this research model, user performance is affected by the deep and surface structure semantics[5] of the conceptual model that is used to represent the focal domain, user characteristics, task characteristics, and a set of moderating variables (e.g. time pressure).

[4] Interestingly, Dunn and Grabski (2001) also found that users of REA-based systems need more time to retrieve information than users of DCA-based systems.

[5] Deep structure semantics refers to the semantics of the focal domain (e.g. the concepts and structure of the business process that is modeled, as for instance prescribed by the REA ontology), whereas surface structure semantics refers to the semantics of the representation tools that are

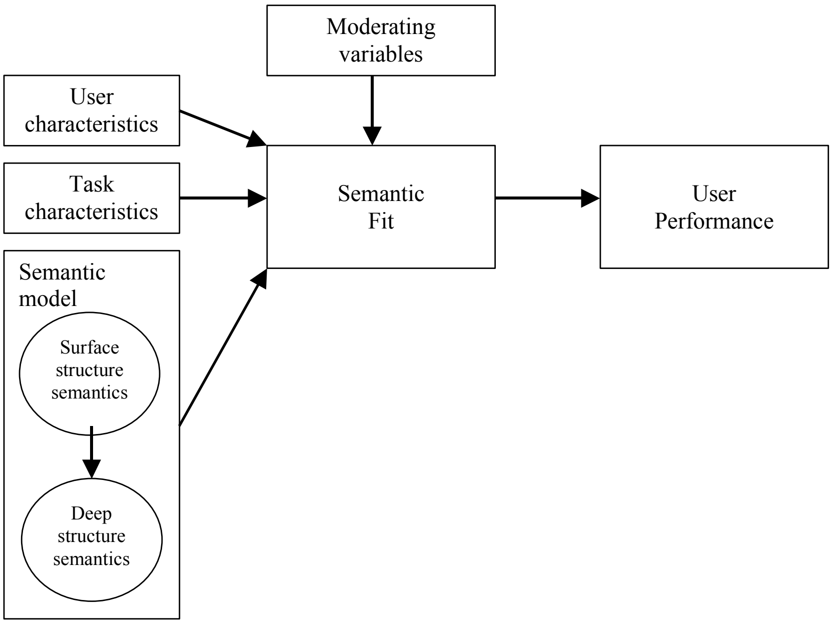

Figure 1. Generic research model based on Dunn and Grabski (2002)

We have further specialized Dunn and Grabski's generic research model in two regards. First, we recognize that most business students will find themselves later in roles requiring a passive use of conceptual schemas (e.g. as system end-users or auditors) rather than an active usage (e.g. database design, system development). Business professionals mainly interact with conceptual schemas by reading (i.e. understanding, interpreting) them. We therefore interpret the user performance variable as the performance on tasks that require comprehension of conceptual schemas.

Second, as moderating variables we explicitly consider domain characteristics for which an impact on user understanding has been demonstrated before. For instance, the scope and nature of the modelled domain determine to a large extent the size and structural complexity of the conceptual schema, and these schema characteristics affect user understanding (Bowen *et al.*, 2004; Genero *et al.*, 2002).

To investigate our first research question, i.e. whether the use of REA patterns in a business process level model increases user comprehension, we manipulate the deep structure semantics factor at two levels: REA and non-REA. As in Poels *et al.* (2004a) we define the REA treatment as performing a comprehension task on an entity-relationship diagram that shows REA pattern occurrence(s) and the non-REA

used to represent the relevant things and properties of the focal domain (e.g. entity-relationship diagrams).

treatment as performing the same comprehension task on an entity-relationship diagram that does not show REA pattern occurrence(s). For ease of reference, the former diagram will be called a REA diagram, whereas the latter diagram is referred to as a non-REA diagram.

At the same time, we exercise control over the other variables: user characteristics (e.g. ability, experience, domain familiarity, problem solving approach, etc.), task characteristics (e.g. nature of the task, task difficulty, etc.), domain (and resulting schema) characteristics (e.g. size, structural complexity, etc.), as well as surface structure semantics (which may impact the effect of deep structure semantics on user comprehension, as indicated in Figure 1). Controlling these variables oversimplifies reality, but in an exploratory stage of the research (as the modelling patterns research is today), attention should be directed first towards the main factor under study, which is the deep structure semantics effect on user comprehension caused by the use of REA patterns.

To operationalize the user comprehension variable, we draw ideas from Topi and Ramesh (2002), Moody (2001), and the studies reviewed in the previous section. Topi and Ramesh (2002) plea for more human factors related research in conceptual modelling and argue that research frameworks should incorporate two different types of dependent variables: objective performance, but also users' attitudes towards tools, tasks, and their own performance. A similar idea is found in Moody's (2001) Method Evaluation Model (MEM) (Figure 2), where objective performance is further operationalized as efficiency and effectiveness, and user attitudes are split out into perceptions, intentions, and behaviour.

To compare the current study with previous studies, in particular the experiment of Poels *et al.* (2004a) that is replicated here, user comprehension will be measured in terms of:

- TIME: Time required to perform a comprehension task (i.e. actual efficiency variable in the MEM; used in most previous studies);
- ACCURACY: Accuracy of comprehension (i.e. actual effectiveness in the MEM; used in most previous studies);
- NORMALIZED ACCURACY: Normalized accuracy (i.e. accuracy score per unit of time, as defined and used in Bodart *et al.* (2001); an overall indicator of actual efficacy, as in the MEM; used in Poels *et al.* (2004a));

- PEOI: Perceived ease of interpretation (i.e. the MEM's perceived ease of use variable as applied to a comprehension task; used in Dunn and Grabski (2001), Dunn and Gerard (2001), and Poels *et al.* (2004a));
- PU: Perceived usefulness (as in the MEM);
- UIS: User information satisfaction (replaces the MEM's intention to use variable; used in Dunn and Grabski (2001), Dunn and Gerard (2001), and Poels *et al.* (2004a)).[6]

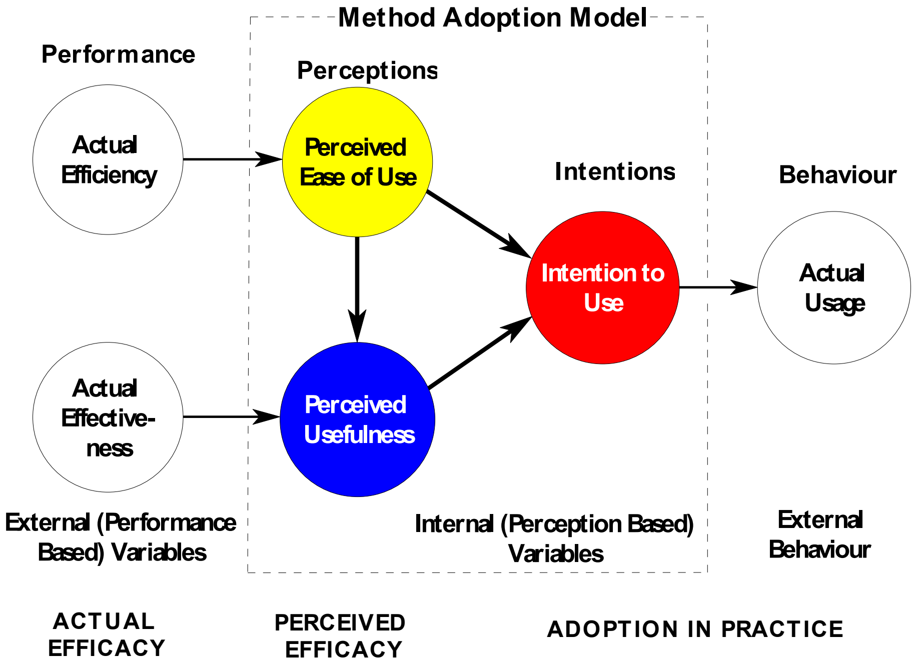

Figure 2. The Method Evaluation Model of Moody (2001)

2.1. Incorporating Perceived Semantic Expressiveness

To investigate our second research question, perceived semantic expressiveness (PSE) must be incorporated in the research framework. Consistent with the MEM, we hypothesize that users that perform better (i.e. better understand the reality

[6] The intention to use a model is perhaps less relevant than it is for methods (i.e. main purpose of the MEM), or information technologies in general (i.e. main purpose of Davis' (1989) Technology Acceptance Model (TAM), from which the Method Adoption Model sub-model of the MEM is derived). A general attitude towards the use of models can be measured in terms of how satisfied users are with the models w.r.t. a comprehension task. This attitude is different from more specific attitudes like perceived ease of use and usefulness, but might be caused by such perceptions. Hence, in a conceptual modelling research context, user information satisfaction is used instead of intention to use.

modelled), develop a more favourable perception of the ease of use and usefulness of the conceptual schema. But if they experience less difficulties in performing the comprehension task with a conceptual schema A than with a conceptual schema B, they might also perceive A to provide a more faithful representation of reality than B, even if A and B are informationally equivalent. Hence, if A and B are informationally equivalent, then differences in PSE might be another indication of differences in user comprehension of A and B. We therefore examine whether (i) the use of a REA diagram leads to higher PSE; and (ii) higher PSE is associated with higher PEOI, PU, and UIS.

Our research model is summarized in Figure 3. As a first and tentative model, we hypothesize that PSE has a direct impact on PEOI and PU, and that it indirectly impacts UIS. The relationships between PEOI, PU, and UIS are based on the Method Adoption Model sub-model of the MEM (replacing intention to use with UIS).

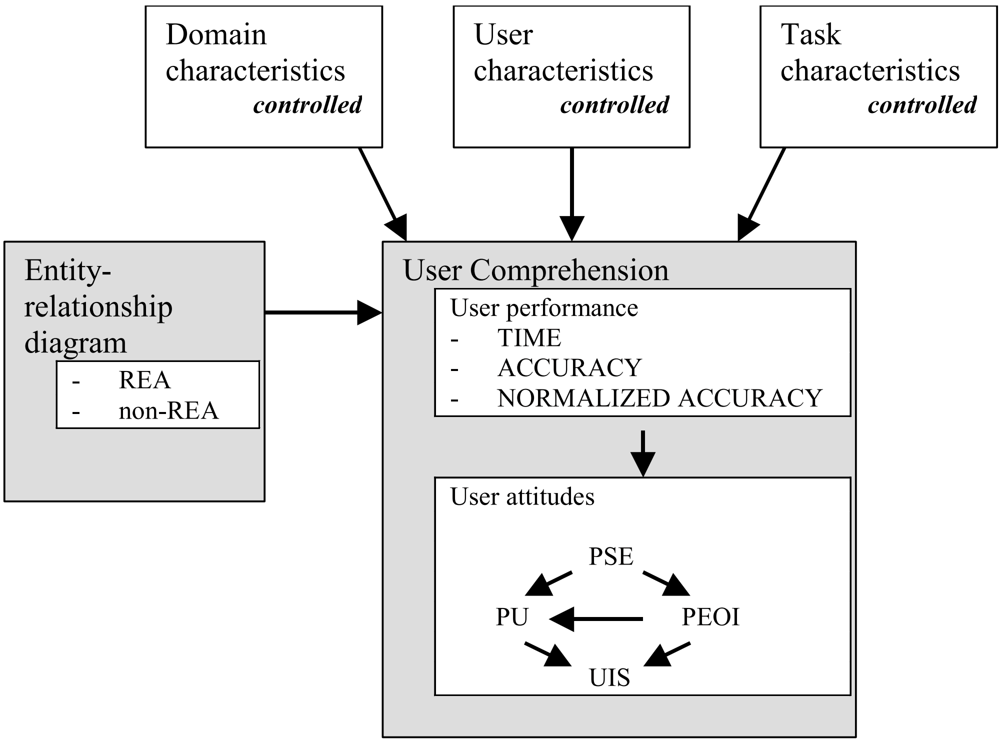

Figure 3. Research framework

Note that also the surface structure semantics variable is controlled as both the REA and non-REA diagrams are offered as entity-relationship diagrams. Moreover, we require that both diagrams are informationally equivalent. Hence, it is possible to perform the comprehension task on either type of diagram. Otherwise, differences in information content may confound differences in user comprehension (Parsons and Cole, 2005). If both diagrams convey exactly the same information about the business process modelled, and controlling for surface structure semantics and domain, task, and user characteristics, then we have sufficient assurance that any observed differences in user comprehension are caused by the treatment. In that case the use or non-use of REA patterns causes the diagrams to be computationally inequivalent.[7]

2.2. Hypotheses to Be Tested

From the research framework a number of hypotheses are derived. The first three hypotheses concern the relationship between the use of a REA/non-REA diagram and user performance with respect to a same comprehension task. We hypothesize that recognizing an REA pattern occurrence in the entity-relationship diagram speeds up schema comprehension (actual efficiency) and allows an interpretation of reality closer to what was intended (actual effectiveness). We also hypothesize an overall effect on actual efficacy.

> H_{TIME}: *Task completion time is less with a REA diagram than with an informationally equivalent non-REA diagram;*
>
> $H_{ACCURACY}$: *Task accuracy is higher with a REA diagram than with an informationally equivalent non-REA diagram;*
>
> $H_{NORMALIZED\_ACCURACY}$: *Task normalized accuracy is higher with a REA diagram than with an informationally equivalent non-REA diagram.*

If the use of a REA diagram is more efficient, then users will perceive a REA diagram as easier to use. If a REA diagram is more effective in supporting the information needs of users performing a comprehension task, then users will perceive a REA diagram as more useful. If a REA diagram is more efficacious (i.e. both effective and efficient) than a non-REA diagram, then users will be more satisfied with the REA diagram. Given a same comprehension task and information equivalence, higher PEOI, PU, and UIS with the REA diagram all indicate that users perceive the REA diagram to be better understood than the non-REA diagram.

[7] Two schemas are computationally equivalent if they are informationally equivalent and any inference that can be easily and quickly drawn from the information given explicitly in one can also be drawn easily and quickly from the information given explicitly in the other, and vice versa (Siau, 2004).

H_{PEOI}: Perceived ease of interpretation is higher with a REA diagram than with an informationally equivalent non-REA diagram;

H_{PU}: Perceived usefulness is higher with a REA diagram than with an informationally equivalent non-REA diagram;

H_{UIS}: User information satisfaction is higher with a REA diagram than with an informationally equivalent non-REA diagram.

We further hypothesize an effect on perceived semantic expressiveness, for reasons explained before.

H_{PSE}: Perceived semantic expressiveness is higher with a REA diagram than with an informationally equivalent non-REA diagram.

Finally, we derive three hypotheses from the user attitudes sub-model in our research framework, postulating relationships between the perception-based variables:

$H_{PSE \rightarrow PEOI}$: Higher perceived semantic expressiveness is associated with higher perceived ease of interpretation;

$H_{PSE, PEOI \rightarrow PU}$: Higher perceived semantic expressiveness and perceived ease of interpretation are associated with higher perceived usefulness;

$H_{PEOI, PU \rightarrow UIS}$: Higher perceived ease of interpretation and perceived usefulness are associated with higher user information satisfaction.

3. Research Method

We replicated the experiment of Poels *et al.* (2004a), taking additional measurements (PSE, PU) and making minor changes to the experiment's design. In a first sub-section we present the design of the experiment. Next the experiment's operation is described.

3.1. Design of the Experiment

The experimental participants were 17 graduate-level business students in an advanced AIS course, where enterprise information modelling was taught using Dunn *et al.*'s pattern-based approach. The modelling module of the course took about 15 hours and students learned to work with the REA pattern templates offered in Dunn *et al.* (2005). The course perspective on enterprise information systems was that of the business professional (in the role of manager, business analyst, system end-user or system auditor). Hence, course exercises included the analysis of business processes based on conceptual schemas, as well as the validation of conceptual schemas with respect to specified end-user data requirements and business policies. As in Dunn *et al.* (2005), REA-patterns-based business process level modelling employed entity-relationship diagrams as a representation tool; the difference with the textbook being the notational system used for such diagrams. Throughout the course (and in the experiment), Chen's (1976) original notation for entity-relationship diagrams was replaced with the notation for Unified Modeling Language (UML) class diagrams (as in Connolly and Begg (2002)).

Given the limited number of students available for our experiment and to control for user characteristics, a within-subjects experimental design was selected. In such a design each participant contributes an observation for each treatment and thus serves as its own control. This presents a deviation from the original experiment reported by Poels *et al.* (2004a), which was between-subjects.

In Poels *et al.* (2004a), participants were offered either a REA diagram or a non-REA diagram showing a consulting services acquisition process. To control for task characteristics, the comprehension task for both diagrams was the same. In a within-subjects experiment, we cannot present participants subsequently two versions (REA and non-REA) of a same conceptual schema, requiring them to perform a same comprehension task. Therefore we extended the original experimental materials with diagrams for a second process, which was a loan financing process. Although the participants had seen in the course REA pattern templates and example diagrams for basic business processes (sales, materials acquisition, payroll), the consulting services acquisition process and loan financing diagrams used in the experiment were new to them.

So in total, four experimental objects (see Appendix A) were used in the experiment, meaning that each business process (hereafter referred to as the 'Consulting' and the 'Finance' processes) was modelled using a REA diagram and an informationally equivalent non-REA diagram. Order of business process modelled and type of diagram were counterbalanced across participants, resulting in an experimental design with four groups of participants, as shown in Table 1.

Table 1. Within-subjects experimental design

Type of diagram	Non-REA				REA			
Business Process	Consulting		Finance		Consulting		Finance	
Order	First	Second	First	Second	First	Second	First	Second
Group	3	4	2	1	1	2	4	3

The REA and non-REA diagrams of the Consulting process were taken directly from Poels *et al.* (2004a), where a specific procedure was followed to operationalize the experiment's treatments. First, a fictitious consulting service acquisition process was specified in an informal, textual format. Next, the appropriate REA pattern templates were instantiated and integrated to create a REA diagram for the Consulting process (Figure A-1). Finally, a non-REA diagram (Figure A-3) was derived from the REA diagram by applying information-preserving diagram transformations.[8]

The idea of the transformations was to create a diagram in which the REA pattern occurrences are no longer easily and quickly recognizable to the user, while preserving information equivalence. Although the non-REA diagram is derived from the REA diagram, the transformations applied make it look as if it does not contain REA pattern occurrences. Apart from safeguarding information equivalence, the transformations do not significantly alter the size and structural complexity of the diagrams (which are schema characteristics to be controlled in the experiment). However, as can be seen in the figures, the diagram layout is changed. The physical positioning of entities and relationships on a diagram may affect user comprehension, and is another potentially confounding factor (Wand and Weber, 2002). The layout design of the non-REA diagram is equally logical and not aesthetically inferior to that of the REA diagram (Poels *et al.*, 2004a). However, the students' familiarity with the REA diagram layout might cause the diagrams to be computationally inequivalent (in the sense that the recognition of REA patterns is impeded when an unfamiliar diagram layout is used).

[8] For a detailed discussion of the transformations applied, and their rationale, we refer to Poels *et al.* (2004a).

We applied the same procedure to create the REA and non-REA versions of entity-relationship diagrams for the loan financing process (see Figures A-2 and A-4 respectively).

Appendix B lists the comprehension questions for the Consulting process used in Poels *et al.* (2004a). The questions are representative of validation type of tasks (e.g. checking a diagram's conformity with textual scenarios describing the business policies that govern a business process) or require interpreting the modelled reality using knowledge previously acquired in the course (e.g. how certain facts about reality, like business policies, can be represented in an entity-relationship diagram). For the Finance process a similar list of questions was conceived (also included in Appendix B).

The number of questions correctly answered was used to measure ACCURACY. The time taken to complete the comprehension task was used for the TIME variable. The correctness score divided by the completion time measures NORMALIZED ACCURACY. These measures for performance-based variables are frequently used for the empirical evaluation of conceptual modelling techniques (Gemino and Wand, 2004).

The perception-based variables and user information satisfaction were measured using an 18-item, 7-point Likert scale questionnaire, included in Appendix C. The measure for PEOI (items 2, 7, 12, 15) was taken from Gemino and Wand (2005). Like the Perceived Ease Of Use (PEOU) instrument used in the original experiment (Poels *et al.*, 2004a) and previous REA-related empirical research (Dunn and Grabski, 2001; Dunn and Gerard, 2001), it has its roots in Davis' (1989) measurement instrument for the TAM, but is adapted to be used with conceptual schema comprehension tasks. The measure for PU (items 6, 10, 17) was not used in previous empirical REA-related research. It is based on Moody's (2001) PU measure for the MEM, and has also its origins in the TAM instrument. The measure for UIS (items 4, 9, 13, 18) was the same as in Dunn and Gabski (2001), Dunn and Gerard (2001), and Poels *et al.* (2004a), and is adapted from Seddon and Yip (1992).

The measure for PSE (items 1, 3, 5, 8, 11, 14, 16) was developed by ourselves. The only REA-related experiment that measured PSE was that of Dunn and Grabski (2000), where they used a one-item 7-point Likert scale to measure PSE (similar to item 3 on our questionnaire) and suggested the development of better measures for PSE as future research.

The theoretical basis for our PSE measure is the semiotics-based framework of Lindland *et al.* (1994) and the ontology-based framework of Shanks *et al.* (2003) for evaluating the quality of conceptual schemas. The development of the measure and a pre-test based on a pilot study (prior to the current experiment) are presented in (Poels *et al*., 2004b), where after item refinement an acceptable reliability level of alpha = 0.75 has been obtained. Furthermore, in this pre-test an inter-item correlation analysis showed the convergent and discriminant validity of the PSE measure vis-à-vis the PEOU, PU, and UIS measures.

3.2. Operational Procedures

The experiment was organized as an exercise directly after the modelling part of the course. As in the original experiment, students were motivated (by the promise of course credits) to perform well, both in terms of accuracy and speed. At the time of the experiment, they were not aware being participants in a research study.

When students entered class, they were randomly allocated to the four groups of the experimental design (confer Table 1). Subsequently, participants were given their first diagram and list of questions. After finishing them (and being timed by us), they received the questionnaire measuring their attitudes (i.e. perceptions and satisfaction) towards the task just accomplished. Next, this procedure was repeated for the second diagram.

4. Data Analysis

Before testing the hypotheses concerning the effect of the experiment's treatments on the dependent variables (sub-section 4.2) and the postulated relationships in the user attitudes sub-model (sub-section 4.3), a reliability and validity analysis of the measurement instrument (i.e. the post-task questionnaire; see Appendix C) was conducted (sub-section 4.1).

4.1. Reliability and Validity Analysis

An inter-item correlation analysis was conducted to test the validity of the measurement instrument for PSE, PEOI, PU, and UIS. Considering the bi-variate correlations of the item scores for a same variable, a possible validity problem with PSE item 11 was indicated, as its scores were not significantly correlated to the scores on any of the other PSE items. Therefore, the participants' scores for this item were not used in the hypothesis testing.

After removing item 11, all other items passed Campbell and Fiske's (1959) convergent and divergent validity test, meaning that each item was more closely associated with the other items of the measure it belongs to, than with the items of other measures. Consistent with (Poels *et al.*, 2004b), we thus obtained evidence that the PSE, PEOI, PU, and UIS items measure different constructs.

It is also important to verify that different people produce consistent results using our measurement instrument. The reliability levels (in terms of Cronbach's alpha) of the different measures (again after removing PSE item 11) are shown in Table 2. They are well above the usual threshold of 0.70 that must be achieved to consider measures as reliable (Nunally, 1978).

Table 2. Reliability of the measures

Measure	Cronbach's alpha
PSE	0.81
PEOI	0.91
PU	0.82
UIS	0.91

4.2. Descriptive Statistics and Hypothesis Testing

Descriptive statistics (mean, median, standard deviation) for the dependent variables are shown in Table 3. The sample size in each cell is 17. As can be seen, all observed differences in treatment means and medians are in the hypothesized direction.

The Kolmogorov-Smirnov test for normality did not demonstrate any deviations from the normal data distribution. Therefore, parametric paired-samples t-tests were used to test the hypothesized effects of the treatments (i.e. using an REA or a non-REA diagram) on the dependent variables. The results of these statistical tests are shown in Table 4.

Table 3. Descriptive statistics by treatment

	REA			Non REA		
	Mean	Median	SD	Mean	Median	SD
TIME (minutes)	28.82	27.00	6.87	32.53	34	6.08
ACCURACY	11.71	12	2.73	10.35	10	2.26
NORMALIZED ACCURACY	0.42	0.42	0.13	0.33	0.29	0.10
PSE	5.07	4.83	0.74	4.59	4.33	0.84
PEOI	4.88	5.00	1.02	3.55	3.5	1.46
PU	5.67	6.00	0.81	4.98	4.67	1.08
UIS	5.43	5.5	0.71	4.44	4.75	1.28

Table 4. Hypothesis testing: results of one-tailed paired-samples t-tests

Hypothesis	t-value	p-value
H_{TIME}: TIME REA < TIME non-REA	-2.626	0.009
$H_{ACCURACY}$: ACCURACY REA > ACCURACY non-REA	2.596	0.010
$H_{NORMALIZED\_ACCURACY}$: NORMALIZED ACCURACY REA > NORMALIZED ACCURACY non-REA	3.277	0.003
H_{PSE}: PSE REA > PSE non-REA	2.923	0.005
H_{PEOI}: PEOI REA > PEOI non-REA	3.899	0.001
H_{PU} : PU REA > PU non-REA	2.853	0.006
H_{UIS} : UIS REA > UIS non-REA	2.864	0.006

Since all p-values are statistically significant, the data collected allows confirming all stated hypotheses. The comprehension task was performed faster and more accurately with the REA diagram than with the non-REA diagram, and the participants perceived the REA diagram to be more semantically expressive, easier to interpret, and more useful than the non-REA diagram. They were also more satisfied after performing the comprehension task with the REA diagram than with the non-REA diagram.

Counterbalancing diagram type and business process modelled alleviates possible order effects. Such effects can still bias the results, for instance when there are differential learning rates for the two treatments (Bodart *et al.*, 2001; Dunn and Gerard, 2001). Therefore the observations were regrouped according to which treatment (non-REA or REA diagram) was administered first. The independent-samples t-test was used to evaluate differences in mean TIME, ACCURACY, NORMALIZED ACCURACY, PSE, PEOI, PU and UIS scores between the group of participants that received a non-REA diagram first and next a REA diagram (8 participants) and the group that started with a REA diagram and continued with a non-REA diagram (9 participants). The results confirm that no distorting effect of the experimental run was present in our data.

A similar post-hoc test was carried out to investigate possible differences in user performance and attitudes that could be caused by the business process modelled (i.e. possible confounding effects of domain and task characteristics). Here only one significant difference in user attitudes was found between the Consulting and Finance diagrams. Participants found the non-REA Finance diagram easier to interpret than the non-REA Consulting diagram ($Mean_{Finance}$= 4.39, $Mean_{Consulting}$= 2.63, independent samples t-test significance: *p =0.008*). As the results of all other tests were not significant, it is unlikely that the business process used had a distorting effect on the experiment results.

4.3. Testing the Role of Perceived Semantic Expressiveness

Table 5 presents the bi-variate Pearson's correlation coefficients of the user attitudes measures. There is no significant correlation between the PSE and PEOI measures. All other correlations are positive and significant.

Table 5. Measure cross-correlation matrix - user attitudes sub-model

	PSE	PEOI	PU	UIS
PSE	1.00			
PEOI	0.092	1.00		
PU	0.582**	0.655**	1.00	
UIS	0.426*	0.711**	0.763**	1.00

** Correlation is significant at the 0.01 level (two-tailed)
* Correlation is significant at the 0.05 level (two-tailed)

We also postulated a number of relationships between the variables of the user attitudes sub-model (confer Figure 3). These and some alternative relationships between the variables were tested through single-variate and multi-variate regression analysis, the results of which are shown in Table 6.

Table 6. Regression analysis - user attitudes sub-model

Regression equation	Dependent variabele	Independent variabele	Regression coefficient	t-value	p-value	R^2
1: $H_{PSE -> PEOI}$	PEOI	PSE	0.092	0.523	0.605	0.023
2	PU	PEOI	0.655	4.908	< 0.001	0.412*
3: $H_{PSE, PEOI -> PU}$	PU	PSE	0.526	5.357	< 0.001	0.685*
		PEOI	0.607	6.182	< 0.001	
4: $H_{PEOI, PU -> UIS}$	UIS	PEOI	0.370	2.668	0.012	0.639*
		PU	0.521	3.764	0.001	
	UIS	PSE	0.172	1.184	0.246	0.643*
		PEOI	0.457	2.927	0.006	
		PU	0.364	1.909	0.066	

* Regression equation is significant at the 0.001 level

Contrary to our expectations, the participants' perception of the semantic expressiveness of the diagrams they worked with during the comprehension task, was not associated to how they perceived the ease of interpreting these diagrams (equation 1).

The other two relationships in our tentative user attitudes model are empirically supported. Both the participants' perception of semantic expressiveness and ease of interpretation have a significant impact on their perception of usefulness (equation 3). Furthermore, adding perceived semantic expressiveness to the original link between perceived ease of use and perceived usefulness in the Method Adoption Model (confer Figure 2), increases the portion of variance in PU that can be explained (i.e. compared to equation 2).[9]

The hypothesized relationship between perceived ease of interpretation and perceived usefulness on the one hand, and user information satisfaction on the other hand, was also confirmed (equation 4). As postulated, perceived semantic

[9] We also tested the significance of the interaction term PSE*PEOI when regressed on PU, but found no significant effect. Considering also the absence of correlation between the PSE and PEOI measurements (confer Table 5), both kinds of perceptions seem to have an independent and roughly equally important (as evidenced by the regression coefficients) impact on how the usefulness of the diagrams for performing the comprehension task was perceived.

expressiveness only indirectly affects user information satisfaction. A model with PSE as a third independent variable does not improve goodness-of-fit (equation 5) and shows that the main effect of PSE is not significant (*p-value of 0.246*).[10]

5. Discussion and Conclusions

The results of the experiment reported in Poels *et al.* (2004a) are largely confirmed in this replication. As in the original experiment, the use of REA diagrams resulted in more accurate performance of the comprehension task and participants perceived such diagrams as easier to interpret than informationally equivalent non-REA diagrams. Furthermore, it was shown that REA diagrams were perceived to be more useful with respect to the comprehension task.

Although in the original experiment the effect on normalized accuracy was significant, contrary to expectations, no efficiency effect was observed.[11] In our replication, however, students could perform more accurate and faster with REA diagrams. Another distinct finding is that the use of REA diagrams left participants more satisfied than when they used non-REA diagrams.

A new result of the study is that after performing a comprehension task, participants perceive REA diagrams as more semantically expressive than non-REA diagrams, even if the diagrams are informationally equivalent (meaning equally correct and complete with respect to the modelled reality). Whereas this might seem a paradox, Siau (2004) argues that informationally equivalent representations are not necessarily perceived as being equivalent by users, depending on their modelling knowledge as obtained through training and experience. It is plausible that the prior training in Dunn *et al.*'s pattern-based approach biased the students' perception of semantic expressiveness in favour of the REA diagrams. The use of REA patterns has been promoted in the course as a good modelling approach. The recognition of these patterns might therefore have strengthened the students' belief about the correctness and completeness of the REA diagrams. The absence of familiar patterns in the non-REA diagrams might have had the opposite effect.

In addition we tested a preliminary user attitudes model that is more complete than what has been used in former REA-related research. We showed that a

[10] Moreover, in the models of equations 4 and 5 no significant interaction terms between the independent variables were found.

modified Method Adoption Model (from Moody's (2001) MEM, and based on Davis' (1989) TAM) holds in our research context, demonstrating that perceived ease of interpretation is related to perceived usefulness, and that both these variables are related to user information satisfaction. Furthermore, we incorporated perceived semantic expressiveness in this model and showed its impact on perceived usefulness. Perceived semantic expressiveness did not directly impact user information satisfaction, but its effect is mediated through the perceived usefulness variable. These results are interesting in the sense that the investigation of the benefits of perceived semantic expressiveness (amongst others increased user satisfaction) has been suggested by Dunn and Grabski (2000).

Contrary to our tentative model, a relationship between perceived semantic expressiveness and ease of interpretation could not be established. These perception-based variables seem to capture different, unrelated constructs of our model. Figure 4 shows our modified user attitudes model, based on the relationships observed in the experiment.

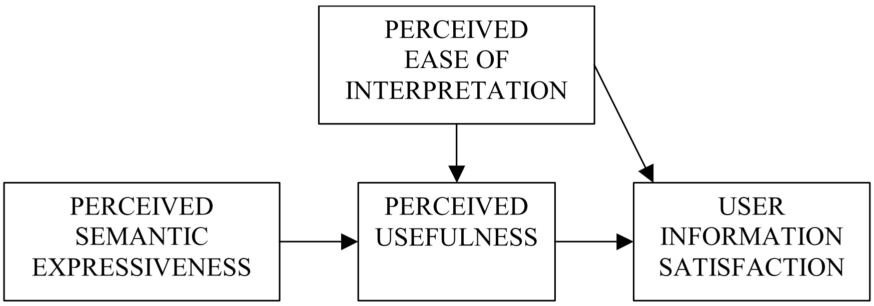

Figure 4. Modified user attitudes model

As a side-effect of the current study, we also collected further evidence of the reliability and validity of our PSE measure. The need to measure the semantic expressiveness of REA-based systems and models, as perceived by system and schema users, has been indicated before (Dunn and Grabski, 2000; Murthy and Wiggins, 2004). Our PSE measure seems to offer a suitable instrument to do so.

5.1. Limitations of the Current Study

One limitation, 'inherited' from the original experiment, concerns the operationalization of the experimental treatments. For two example business

[11] This was ascribed in Poels et al. (2004a) to a lack of statistical power.

processes, two informationally equivalent versions of a same entity-relationship diagram were derived. A first diagram (called REA diagram) showing obviously the presence of REA pattern occurrences (in particular REA's core transaction pattern); a second diagram (called non-REA diagram) hiding these pattern occurrences through information-preserving transformations. This treatment operationalization is of course only a proxy for comparing the user understanding of a patterns-based schema against that of a schema not derived by applying pattern templates. On the other hand, it is hard to imagine how such schemas could have been independently developed, while preserving information equivalence. Furthermore, the working hypothesis was that participants would easily and quickly recognize the REA patterns in the REA diagrams, but not in the non-REA diagrams. The experiment results seem to support this working hypothesis.

To recognize pattern occurrences, patterns must have been learned and stored in long-term memory (Batra and Wang, 2004). Therefore the experiment employed as participants students familiar with REA patterns. Consequently, we abstain from generalizing the study results to conceptual schema users not introduced to REA-patterns-based modelling. This does not diminish the value of our study as the goal was to evaluate the actual and perceived efficacy of Dunn *et al.*'s approach for educating business students in enterprise information modelling.

Finally, a threat to external validity is posed by controlling the surface structure semantics, domain, task, and user characteristics in the experiment. As far as the domain factor is concerned, we don't know if the observed results still hold when business process schemas are scaled up to larger, possibly enterprise-wide schemas. Further, very little is known on the interaction between modelling formalism, user, and task (Topi and Ramesh, 2002). For instance, Arisholm and Sjoberg (2004) observed different experiment results depending on the skill and experience of the participants. It is therefore hard to infer what would be the results if other levels for the controlled variables were chosen.

5.2. Future Research

The concerns raised above may be addressed in future research. In particular the impact of task complexity on the benefits of a patterns-based modelling approach is a worthwhile investigation, as Batra and Wishart (2004) found different results when varying the level of task complexity.

Future research may also consider other types of model usage. Information equivalence is no longer an issue if participants are required to construct conceptual schemas (instead of interpreting given schemas). In such an evaluation study, the use of an REA-patterns-based approach can be contrasted against the use of an alternative approach (or an approach based on other patterns), and user performance can be directly compared based on the quality and resource consumption of the schemas produced.

We also repeat previously made suggestions (see e.g. Dunn and Grabski (2002), Wand and Weber (2002), Gemino and Wand (2004)) to base experimental hypotheses on stronger theoretical foundations, for instance using theories of cognition and learning. As a working hypothesis we assumed the presence of a 'pattern recognition' mechanism that causes the observed differences in user comprehension. It remains to be investigated what elements in the REA enterprise domain ontology trigger this mechanism.

In our own further work we focus on the proposed user attitudes model, in particular on the role of perceived semantic expressiveness herein. We wish to further validate (and possibly refine) the model, develop its theoretical underpinnings, as well as investigate relationships with other variables of interest (like performance-based variables of user comprehension and other model-usage factors). Testing such relationships was outside the scope of the current study.

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Appendix A: Experimental objects

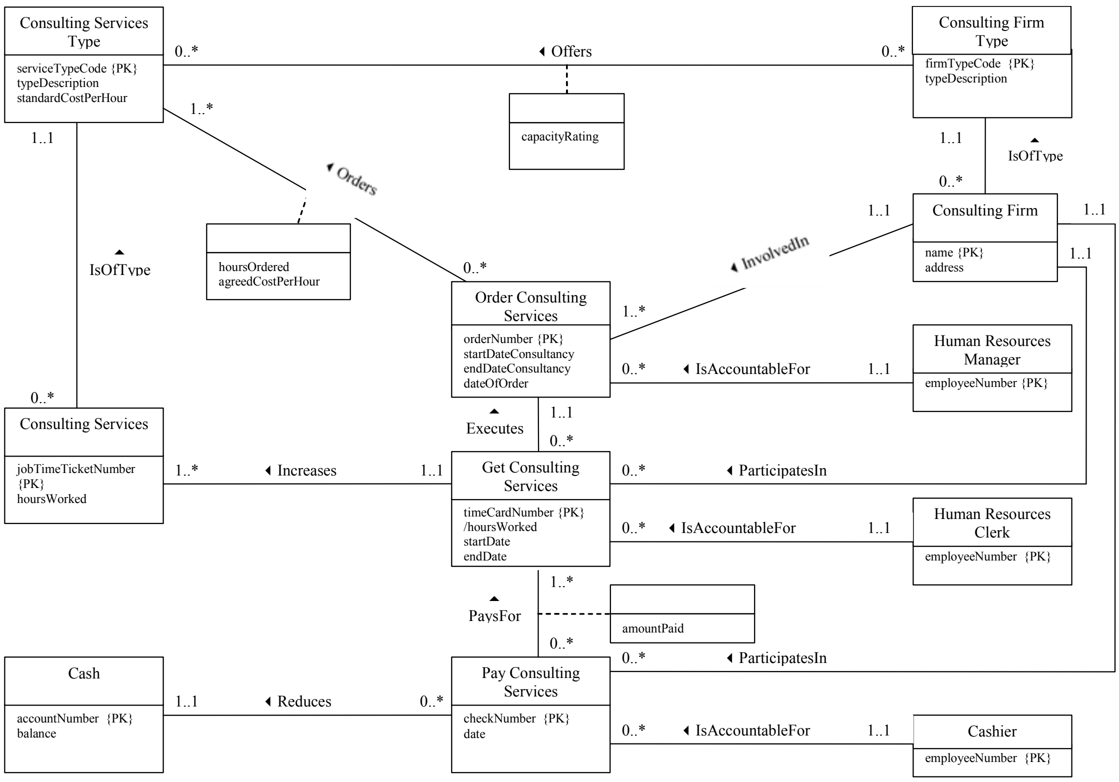

Figure A-1. REA diagram Consulting process

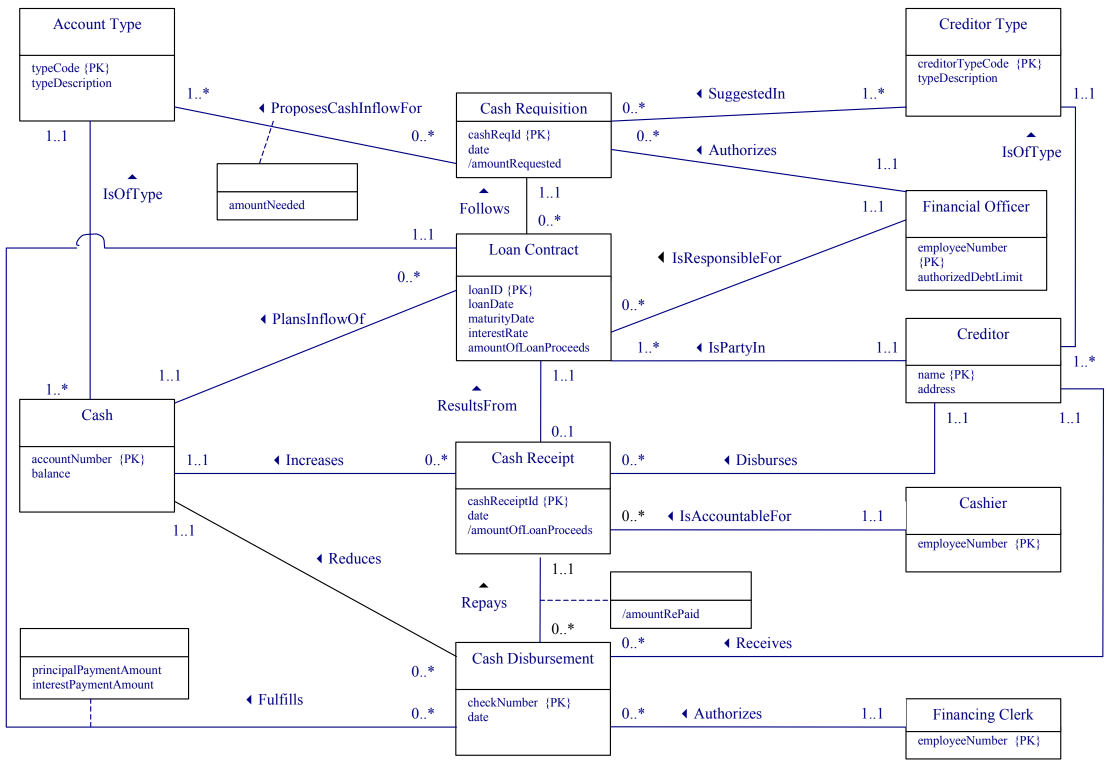

Figure A-2. REA diagam Finance process

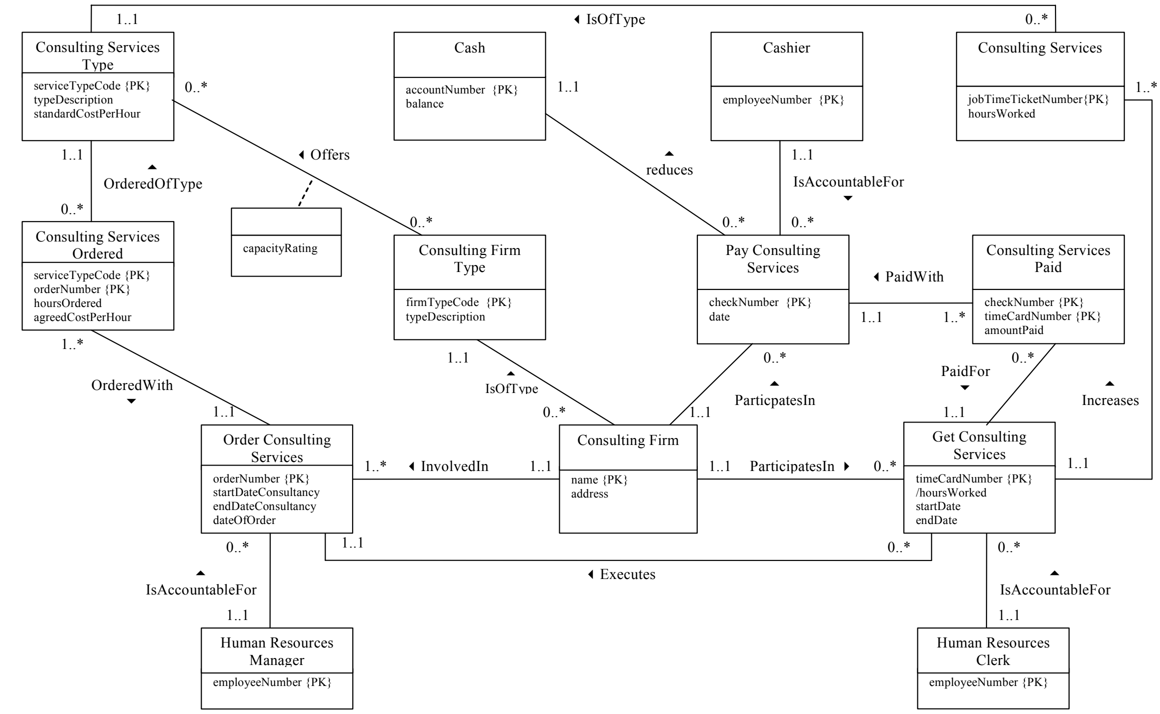

Figure A-3. non-REA diagram Consulting process

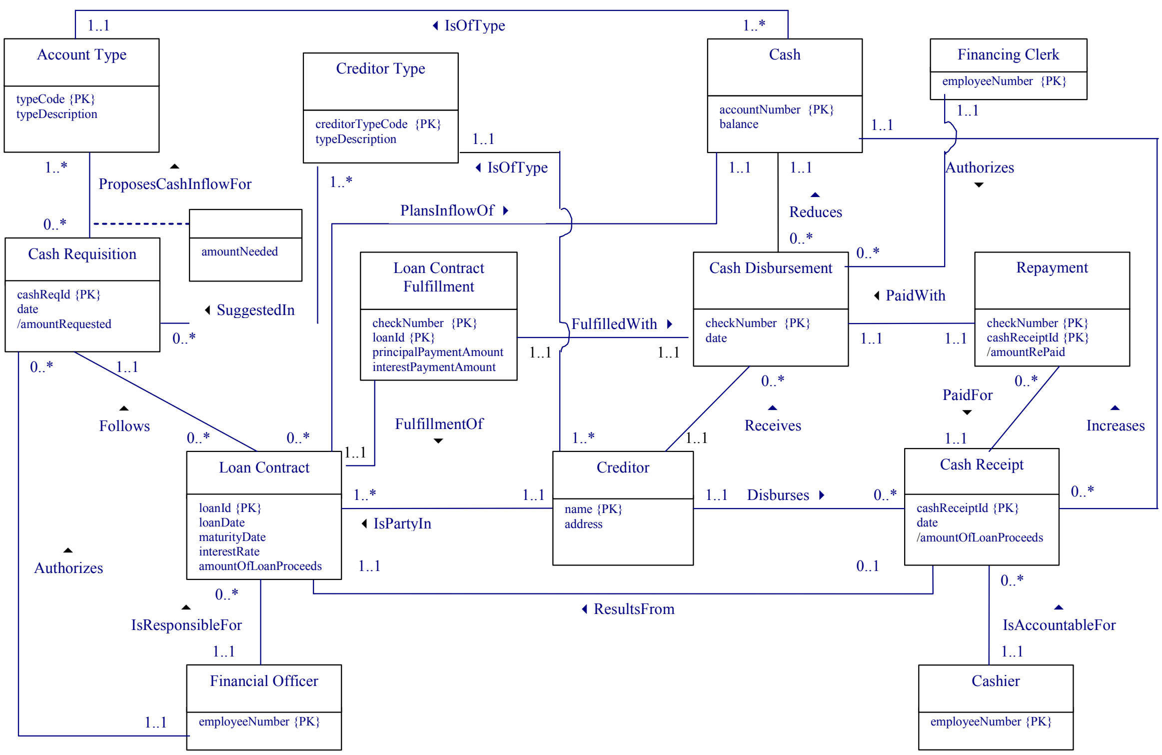

Figure A-4. non-REA diagram Finance process

Appendix B: Experimental tasks

Consulting process questions

1. Can the company make partial payments for consulting services that are registered on a same time card ?
2. Must the amounts that are paid to a same consulting firm for consulting services registered on different time cards be drawn from a single cash account ?
3. List the entity types that represent economic resources (i.e. valuable assets) that are affected by the transactions modelled in the diagram.
4. Does the conceptual schema allow calculating at any time the balance of the accounts payable to consulting firms ?
5. Can the conceptual schema be used by a company where several human resources clerks are allowed to register consultancy hours on the same time card (and be held accountable) ?
6. Can the conceptual schema be used by a company where every consulting hour registered on a job time ticket must also be registered on a time card ?
7. Can the conceptual schema be used by a company that has human resources managers that never order consulting services ?
8. Can the conceptual schema be used by a company where the human resource clerks are only allowed to process time cards that relate to orders by the same human resources manager?
9. Can the conceptual schema be used by a company where more than one cashier can be hold accountable for paying the consultancy hours that are registered on a same time card?
10. Can the conceptual schema be used by a company that wants to issue a single payment check to pay for consulting services related to more than one order ?
11. Can the conceptual schema be used by a company that allows to register consulting hours related to different consulting service types on the same time card ?
12. Can the conceptual schema be used by a company that wishes to pay for consulting services that are ordered but not yet delivered ?
13. Can a capacityRating apply to a consulting firm if the company has never ordered consulting services with that consulting firm ?
14. Can the hours worked that are registered for some consulting service on the same job time ticket (identified by its jobTimeTicketNumber) be ordered by more than one human resources manager ?
15. What type of business process is modelled in the diagram ?
16. Does the diagram depict a closed value cycle ?

Finance process questions

1. Can there be a cash account whose balance is increased by a cash receipt, without there being a loan contract ?
2. Must the amounts that are paid in fulfilment of a loan contract always be drawn from the same cash account?
3. List the entity types that represent economic resources (i.e. valuable assets) that are affected by the transactions modelled in the diagram.
4. Does the conceptual schema allow calculating at any time the proportion of the loan proceeds that has already been repaid ?
5. Suppose a cash requisition is followed by a single loan contract. Can the conceptual schema be used by a company where the financial officer that has authorized a cash requisition is different from the financial officer that is responsible for the loan contract ?
6. Can the conceptual schema be used by a company where a payment of interest may be made in fulfilment of more than one loan contract ?
7. Can the conceptual schema be used by a company that requires that all loan contracts that follow a same cash requisition are made with creditors of the same creditor type ?
8. Can the conceptual schema be used by a company that allows a creditor to disburse the loan proceeds that are specified in a loan contract using several transactions ?
9. Can the conceptual schema be used by a company that wishes to repay a loan with a single cash disbursement ?
10. Can the conceptual schema be used by a company that requires that all cash disbursements for repaying loans that are authorized by the same financing clerk fulfil loan contracts for which the same financial officer is responsible ?
11. Can the conceptual schema be used by a company that requires that each cash disbursement that is authorized for loan repayment is linked to a single cash requisition ?
12. Can the conceptual schema be used by a company that wishes to start with interest payments in fulfilment of a loan contract before the loan proceeds have been received ?
13. Can we determine the creditor type of a creditor with whom the company has no loan contract ?
14. Can more than one financial officer be responsible for loan contracts with a particular creditor ?
15. What type of business process is modelled in the diagram ?
16. Does the diagram depict a closed value cycle ?

Appendix C: Post-task questionnaire

	Strongly Disagree	Disagree	More or less disagree	No preference	More or less agree	Agree	Strongly Agree
1. The conceptual schema represents the business process correctly.	❑	❑	❑	❑	❑	❑	❑
2. It was easy for me to understand what the conceptual schema was trying to model.	❑	❑	❑	❑	❑	❑	❑
3. The conceptual schema provided me with a realistic representation of the business process.	❑	❑	❑	❑	❑	❑	❑
4. The conceptual schema adequately met the information needs that I was asked to support.	❑	❑	❑	❑	❑	❑	❑
5. The conceptual schema contains contradicting elements.	❑	❑	❑	❑	❑	❑	❑
6. Overall, I think the conceptual schema would be an improvement to a textual description of business process	❑	❑	❑	❑	❑	❑	❑
7. Using the conceptual schema was often frustrating.	❑	❑	❑	❑	❑	❑	❑
8. The conceptual schema contains redundant elements.	❑	❑	❑	❑	❑	❑	❑
9. The conceptual schema was not efficient in providing the information I needed.	❑	❑	❑	❑	❑	❑	❑
10. Overall, I found the conceptual schema useful for understanding the process modelled.	❑	❑	❑	❑	❑	❑	❑
11. Elements must be added to faithfully represent the business process.	❑	❑	❑	❑	❑	❑	❑
12. Overall, the conceptual schema was easy to use.	❑	❑	❑	❑	❑	❑	❑
13. The conceptual schema was effective in providing the information I needed.	❑	❑	❑	❑	❑	❑	❑
14. All the elements in the conceptual schema are relevant for the representation of the business process.	❑	❑	❑	❑	❑	❑	❑

	Strongly Disagree	Disagree	More or less disagree	No preference	More or less agree	Agree	Strongly Agree
15. Learning how to read the conceptual schema was easy.	❑	❑	❑	❑	❑	❑	❑
16. The conceptual schema gives a complete representation of the business process.	❑	❑	❑	❑	❑	❑	❑
17. Overall, I think the conceptual schema improves my performance when understanding the process modelled.	❑	❑	❑	❑	❑	❑	❑
18. Overall, I am satisfied with the conceptual schema for providing the information I needed.	❑	❑	❑	❑	❑	❑	❑

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