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# WORKING PAPER

# The Pragmatic Quality of Resources-Events-Agents Diagrams: An Experimental Evaluation

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# The Pragmatic Quality of Resources-Events-Agents Diagrams: An Experimental Evaluation

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**Abstract.** The Resources-Events-Agents (REA) model is a semantic data model for the development and integration of conceptual schemas of accounting information systems. Although in the Accounting Information Systems literature, the REA model is proposed as a benchmark against which to evaluate newly proposed accounting data models, only few studies have been undertaken to empirically validate the claimed benefits of REA modeling. Moreover, these studies focused on REA-based accounting system implementations and not on problem space representations. The work presented in this paper addresses this gap. Starting from theoretical frameworks for conceptual model quality and method evaluation in the IS field, and from previous research on comparative analysis of data modeling formalisms, a laboratory experiment was organized to evaluate the understanding of diagrammatic conceptual schemas that are developed using the REA model. The experimental results indicate that the REA modeling of accounting systems is effective in terms of the accuracy of understanding. On the other hand, little support was found for its efficiency in terms of faster comprehension of schemas that are developed according to the REA model.

## 1 Introduction

The Resources-Events-Agents (REA) accounting model (McCarthy, 1982) is a semantic data model for representing basic economic exchanges such as 'sale – cash receipt' and 'purchase – cash disbursement' (called transaction cycles in accounting (McCarthy, 1999)). The core of the REA model is a set pattern of relationships between three kinds of entities (economic resources, economic events, economic agents) that are involved in a transaction cycle (David et al., 2002). Stock-flow relationships associate resources with the events that effectuate the flows in and out of the resources. For each event effectuating an inflow there is an event effectuating an outflow. This dual nature of an economic exchange is modeled by a duality relationship between the events. Finally, participation relationships associate events with their participating agents. In each event participate an agent internal to the company (i.e. inside participation) and an external agent, like a customer or vendor (i.e. outside participation). This reusable modeling pattern is described in the Basic REA Template shown in Figure 1.

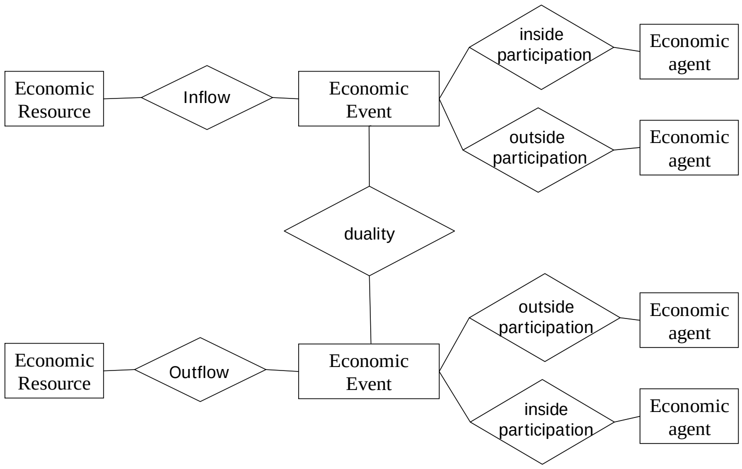


**Figure 1.** The Basic REA Template (based on McCarthy (2003))

Although the use of the REA model for the semantic modeling of accounting systems is not tied to a particular modeling formalism (Dunn and McCarthy, 1997), the Entity-Relationship (ER) model (Chen, 1976) is the preferred and most often used format for the REA model (Dunn and Gerard, 2001; Dunn and Grabski, 2001). A REA diagram can thus be described as a diagrammatic ER representation of a transaction cycle that is obtained through the instantiation of the Basic REA Template (Romney and Steinbart, 2003). Figure 2 shows for instance a REA diagram of the expenditure cycle in a retail company.

The instantiation of the generic pattern that is captured in the Basic REA Template is the main activity in the REA modeling of a transaction cycle. The repeated use of this occurrence template for establishing an accountability infrastructure is also the most distinguishing feature of REA modeling (Dunn and McCarthy, 1997). Subsequent REA modeling activities include specifying cardinality constraints to express business rules, describing properties of entities and relationships by means of attributes, and integrating transaction cycle schemas into an overall REA diagram of the accounting information system.[1]

From an Accounting Information Systems (AIS) research point of view, the REA model is the most significant and influential proposal for the semantic modeling of information systems that track economic phenomena (Daigle and Arnold, 2000; Poston and Grabski, 2000; Samuels and Steinbart, 2002). Dunn and McCarthy (1997) contend that any research outputs in events and database accounting that ignore the contributions of the REA model to the semantic modeling of accounting systems would not be justifiable as advances in the field. Supported by March and Smith's IT

[1] A description of the REA modeling process and activities can be found in Romney and Steinbart (2003).

research framework (March and Smith, 1995), Dunn and McCarthy also argue that researchers that propose alternative accounting data models should demonstrate that their alternatives "evaluate" well against the REA model on some definite performance metrics.

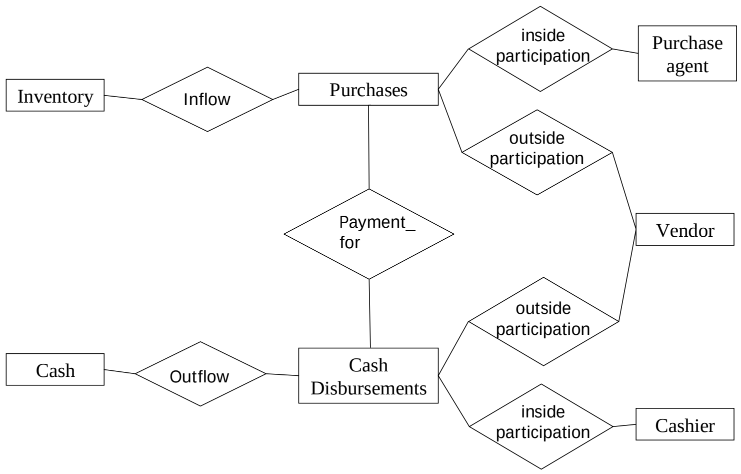


**Figure 2.** REA diagram of the expenditure cycle in a retail company

The status assigned to the REA model derives mainly from the observation that it is the only accounting data model with a structuring orientation in the sense that a normative structure is imposed on the conceptual schema (Dunn and McCarthy, 1997).

Dunn and McCarthy (1997) admit, however, that the benefits of having a structuring orientation are only hypothesized and have not been subjected to empirical testing. Empirical evidence for this and related claims such as semantic expressiveness[2] (McCarthy, 1982) and the improved readability of REA diagrams due to an indexing mechanism[3] inherent in the Basic REA Template (Dunn and Gerard, 2001; Romney and Steinbart, 2003) is scarce and mostly of a recent date.

Dunn and Grabski (2000) demonstrated experimentally that users perceive an accounting system based on the REA model as more semantically expressive than a

[2] Semantic expressiveness refers to how well a model reflects the underlying reality that is represented (Dunn and Grabski, 2000). Dunn and McCarthy (1997) state that the semantic expressiveness of the REA model results in systems that are better understood by users.

[3] A layout design where the entities representing economic resources, economic events, and economic agents are placed in respectively a left, middle and right column of the diagram. Additionally, the top-down ordering of the entities that represent events may reflect the sequence of event occurrences (i.e. the temporal relationships between the 'event' entities). These are diagrammatic conventions, but not mandatory rules of REA modeling (Romney and Steinbart, 2003).

system based on the traditional Debit-Credit-Account (DCA) model. They also showed that higher perceived semantic expressiveness is associated with higher task accuracy in information retrieval. However, the study did not directly compare the REA model against the DCA model. The participants were given proxy accounting system implementations in the form of a relational logical database model (for REA) and sample journals and ledger accounts (for DCA). Moreover, example source documents turned out to be necessary to retrieve some of the required information when the DCA-based system was used (Summers, 2000).

In a related study, Dunn and Grabski (2001) showed that the structuring orientation of the REA model resulted in a greater degree of localization (i.e. the grouping together of the information that must be retrieved) and better user performance in information retrieval tasks, as compared to a DCA-based system. As in their previous study, the experimental objects included the conceptual schema (REA diagrams versus a complete chart of accounts), relational table definitions (as an implementation of the REA-based system) and sample source documents.

In another experimental study, Dunn and Gerard (2001) observed greater efficiency in information retrieval tasks when REA modeling employs a diagrammatic representation (ER) instead of a linguistic representation (Backus-Naur form). Although this study differs from the others in the sense that it uses experimental objects at the conceptual modeling level, it is an intra-grammar study (Wand and Weber, 2002) which does, by itself, not validate the REA model.

Summarizing, none of the reviewed empirical studies were aimed at evaluating the REA model as a conceptual modeling tool for accounting information systems. We belief that before the REA model can be proposed as a benchmark against which alternative accounting data models must be evaluated, it needs proper evaluation itself, even if many of its claimed benefits seem natural and logical.

This work intends to contribute towards a systematic evaluation of the REA model as an AIS conceptual modeling tool. It reports on a laboratory experiment that was aimed at a comparative analysis of user comprehension of informationally equivalent REA and non-REA diagrams.[4] The basic assumption is that the REA model, if it is to be considered valuable, must have at least an added value on top of the ER model that is generally used as its operational modeling formalism. Although we acknowledge the merits and scientific contributions of the previous empirical studies, the research question tackled in this paper is of a different, and perhaps more fundamental, nature.

The structure of the paper is the following: Section 2 presents the theoretical background underlying the proposition tested in this research. Section 3 describes the design and execution of the experiment. The analysis and interpretation of the results is discussed in section 4. Finally, section 5 contains conclusions and discusses future research directions.

[4] For the purposes of this paper we define a non-REA diagram as an ER diagram that is not obtained through the instantiation of the Basic REA Template. Information equivalence is a concept defined in Larkin and Simon (1987). If representations are informationally equivalent, then all information in one representation is inferable from the other and vice versa.

## 2. Theoretical Background and Proposition

A theoretical basis for the systematic evaluation of the REA model can be found in the framework for quality in conceptual modeling of Lindland et al. (1994). This framework, grounded in linguistics and organizational semiotics (Stamper and Liu, 2000), distinguishes three types of quality based on the correspondence between four sets of statements:[5] the set of statements allowed by the language, the set of statements that would be correct and relevant for describing the problem domain, the set of statements actually made, and the set of statements that users think the conceptual schema contains (Figure 3). Syntactic quality describes how well the schema follows the rules of the language. Semantic quality describes how well the schema corresponds to the problem domain. Finally, pragmatic quality captures how well the schema is understood by its users. For each of these quality types, goals are formulated and means to achieve or improve the goals are identified. Quality achievement/improvement means include modeling activities and language or schema properties.

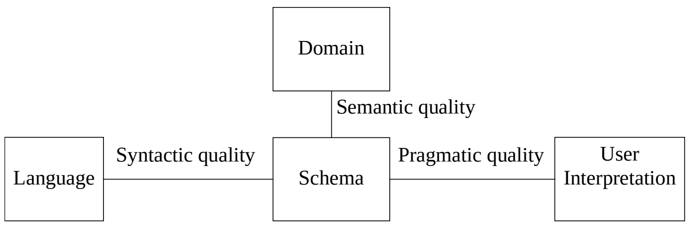


**Figure 3.** Lindland et al.'s framework for quality in conceptual modeling

The framework suggests a systematic evaluation of the REA model would consider syntax, semantics and pragmatics. Recent survey research has shown that syntactic quality issues in conceptual modeling seem to be well understood and supported by automated tools (Poels et al., 2002). Therefore the main evaluation effort would be directed towards semantic and pragmatic quality. The goals for semantic quality are validity and completeness, meaning a correspondence between the schema and the problem domain. The semantic quality of a schema is, however, hard if not impossible to evaluate as it requires observing and interpreting the problem domain (i.e. the 'real world'). Krogstie et al. (1995b) therefore extended the framework with a fourth quality type, perceived semantic quality, which is described as the correspondence between the set of statements that users think the schema contains and the set of statements that users think the schema should contain, based upon their knowledge of the problem domain (Figure 4).

[5] According to Lindland et al. (1994) modeling is making statements in some language. The REA model is in this sense a language (or a grammar following conventional conceptual modeling terminology (Wand and Weber, 2002; Parsons and Cole, 2003), whereas a REA schema is a collection of statements (also called script (Parsons and Cole, 2003)). A REA diagram is a REA schema that is represented in a diagrammatic format following the ER modeling formalism.

Improving pragmatic quality helps closing the gap between perceived semantic quality and actual semantic quality. In terms of the framework, improving pragmatic quality means increasing the degree of correspondence between the set of statements in the schema and the set of statements the user thinks the schema presents (i.e. their understanding of the schema). The better the schema is understood, the better an evaluation instrument for perceived semantic quality can be used to assess the actual semantic quality of the schema.[6] Lindland et al. (1994) also contend that improvements in pragmatic quality can improve semantic quality by making it easier to detect invalidity and incompleteness. An adequate understanding of AIS conceptual schemas by future accounting system users[7] is therefore essential in the process of validating the user requirements captured in the schemas. Moreover, accounting model users such as auditors need to understand representations of reality in order to make inferences upon reality (like identifying the need for internal controls). Consequently we focused the attention towards the evaluation of the pragmatic quality of REA diagrams, from a business user's point of view, leaving the evaluation of (perceived) semantic quality as a topic for future research.

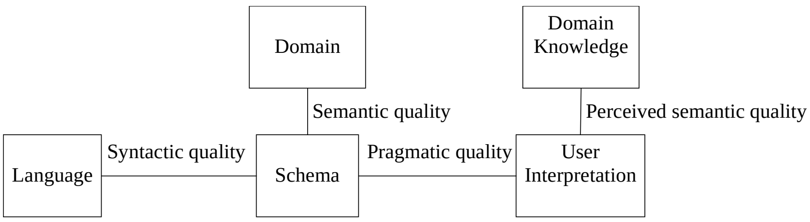


**Figure 4.** The Lindland/Krogstie extended framework for quality in conceptual modeling

Previous research on Conceptual Modeling Quality (CMQ) offers some support for the notion of the REA model as a quality assurance tool for the conceptual modeling of accounting systems. Structure, for instance, has been mentioned by Lindland et al. (1994) as a quality-carrying property of a schema directed specifically towards a better understanding. In his quality framework for ER diagrams, Kesh (1995) postulates a causal relationship between suitability of structure, i.e. how well the

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[6] Of course there is still the gap between the domain and the knowledge of this domain possessed by the stakeholders in the conceptual modeling process. The degree of correspondence between domain and domain knowledge has been described by means of constructs such as domain-audience appropriateness (Lindland et al., 1994), knowledge quality (Krogstie, 1998) and perceptual quality (Nelson et al., 2001). This quality type is not within the scope of our current work as it is not a property of the conceptual schema (nor the language). Furthermore, making observations or inferences about the domain requires taking an epistemological standpoint based on well-founded assumptions, for instance ontological assumptions (see Schütte, 1999) for a treatment on the philosophical aspects of quality evaluation in the field of conceptual modeling). Our point of view on conceptual model quality is more a practically-oriented one, based on method evaluation approaches in the IS field (see next section).

[7] The primary stakeholder in the modeling process that is concerned with understandability is the business user (Moody and Shanks, 2003).

structure of the diagram reflects the structure of the problem domain, and usability. Krogstie et al. (1995a) list graph aesthetics and diagram layout amongst the means to achieve pragmatic quality. The Guidelines of Modeling (GoM) of Schütte and Rotthowe (1998) include layout design in the 'Principle of Clarity' and consider it as an element supporting the lucidity, and hence comprehensibility of a schema. Finally, in their research agenda for information systems and conceptual modeling, Wand and Weber (2002) postulate that the physical rearrangement of the entities and relationships on an ER diagram affects user comprehension.

Of all CMQ models mentioned, only the proposal of Lindland et al. (1994) has been empirically tested as a quality evaluation framework for conceptual schemas (Moody et al., 2002; 2003). These experimental tests did, however, not include the hypothesized causal relationships between the quality means and goals in the framework. Moreover, as remarked by Lindland et al. (1994), the framework was not intended as a practical evaluation framework for assessing the quality of conceptual schemas. Its primary ambition was to develop an understanding of what quality means in conceptual modeling.

The quality-carrying properties diagram structure and aesthetics of diagram layout mentioned in the CMQ models are properties assured by the structure-orientation and diagrammatic conventions of the REA model. Despite the scarcity of thoroughly validated theories, both the REA-related research and the understanding of quality types, goals and means in the CMQ field allow making the following proposition:

*The user comprehension of a REA diagram is better than the user comprehension of an informationally equivalent non-REA diagram.*

## 3. Definition, Planning, and Operation of the Experiment

To test the proposition, we undertook a laboratory experiment. This section describes the design and execution of the experiment. The next section presents and discusses the results of the statistical tests on the collected data.

### 3.1. Development and Formulation of Hypotheses

The basis for developing the proposition was the need to evaluate the REA model. The main activity in using this model involves instantiating the generic pattern of an economic exchange that is captured in the Basic REA Template, to create a pattern occurrence for a target transaction cycle. The use of the REA model is thus prescribed by a conceptual modeling method, REA modeling, that provides guidance on how to develop, represent (e.g. in a REA diagram) and integrate the conceptual schemas of an accounting information system.

Since the REA accounting data model comes together with a modeling method (i.e. REA modeling) prescribing its use, further support for the systematic evaluation of the REA model can be found in method evaluation research. An evaluation framework that was specifically conceived for IS design methods is the Method Evaluation Model (MEM) of Moody (2001). The core of the MEM is called the

Method Adoption Model (MAM). This MAM is based on constructs and relationships of Davis' Technology Acceptance Model (TAM) (Davis, 1989), which is an evaluation framework for information technology in general.

Figure 5 shows the constructs of the MEM and the causal relationships between them. Although the MEM considers adoption in practice as the ultimate criterion of a method's success, other variables can be measured and evaluated to predict the acceptance of a method. One of these variables is efficacy, which combines efficiency (the extent to which a method reduces the effort to perform a task) and effectiveness (the extent to which the method improves the quality of the result) (Moody et al., 2003).

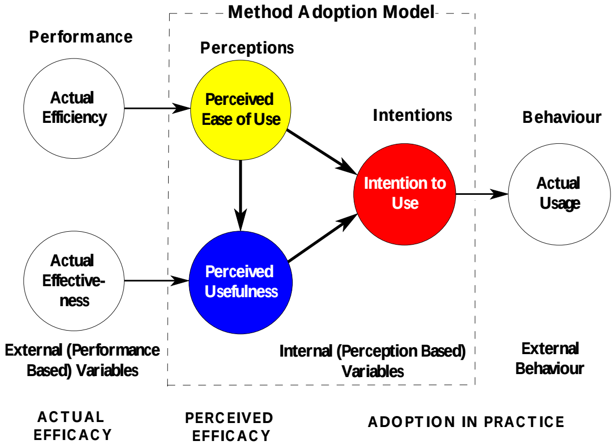


**Figure 5.** Moody's Method Evaluation Model

Investigating the efficiency and effectiveness of conceptual modeling grammars is identified as a major research opportunity by Wand and Weber (2002). Then again, a grammar (e.g. the REA model) cannot be efficient or effective per se; it is the use of a grammar (i.e. REA modeling) that determines its efficiency and effectiveness with respect to conceptual modeling tasks. It is this mutual dependency between a grammar (REA model) and its use (REA modeling) that motivated us to operationalize the theory-based proposition using Moody's MEM. By combining a method evaluation framework such as the MEM with a CMQ model such as the Lindland/Krogstie framework, a practical evaluation component is added to an essentially theory-based and descriptive framework of quality in conceptual modeling.

Efficacy can be performance-based or perception-based. As this research was a first attempt to evaluate REA modeling in a systematic way, it was chosen to focus on a performance-based evaluation of the method's efficacy (i.e. actual efficacy), leaving a perception-based evaluation as another topic for future research.

The evaluation of the efficacy of a grammar (actually the use of the grammar as prescribed by the modeling method) can be done in the context of script creation or script interpretation tasks (Wand and Weber, 2002). Given the focus on pragmatic quality, the appropriate context here is script interpretation. In other words, the REA model / REA modeling was evaluated with respect to its efficiency and effectiveness in schema comprehension.

As the Lindland/Krogstie framework considers schema quality and not language quality, the evaluation of the REA model / REA modeling was done via the product it produces, i.e. a REA diagram. If it is shown that the pragmatic quality of a REA diagram is higher than that of an informationally equivalent non-REA diagram, then empirical evidence is gathered on the efficacy of the REA model / REA modeling in terms of improved user comprehension.

Following the MEM, the concept of user understanding was operationalized using three performance-based variables: actual efficiency, actual effectiveness and actual efficacy. The latter variable is a combination of the former two and is defined analogous to the concept of productivity (i.e. relating an output variable to an input variable). Hence, for the purpose of the experiment, efficacy was defined as the ratio of effectiveness to efficiency. This reflects the idea that there might be a trade-off between the effectiveness and efficiency dimensions of user comprehension: a better comprehension may be compromised by a faster comprehension. It also reflects the idea that a perfect comprehension is not necessarily the end-goal for pragmatic quality.[8]

Our choice of measures for these variables was guided by similar research in the field of conceptual modeling (see Wand and Weber (2002), Parsons and Cole (2003), and Gemino and Wand (2003) for recent overviews). As in Bodart et al. (2001), Genero et al. (2002), Shoval et al. (2002), and Parsons (2003) comprehension time was chosen as a measure of the efficiency of user comprehension. Comprehension time was defined as the time required to complete a comprehension task. This time includes reading the questions that were formulated to assess user comprehension, solving the problems posed by these questions through analysis of the experimental object (i.e. a REA or non-REA diagram), and answering the questions by writing down the solutions. The effectiveness of user comprehension is measured by the accuracy of comprehension, which is defined as the ratio of the number of correctly answered questions to the total number of questions that make up the comprehension task (Kim and March, 1995; Siau et al., 1997; Bodart et al., 2001; Shoval et al., 2002; Burton-Jones and Weber, 2003; Parsons, 2003). Finally, the efficacy of user comprehension was measured with the normalized accuracy measure that was defined by Bodart et al. (2001) as the ratio of the accuracy of comprehension to the comprehension time.

In the operational hypotheses the direction of the effect is stated given the alleged benefits of REA modeling.

$H_{efficiency}$: *The comprehension time for a REA diagram is less than the comprehension time for a non-REA diagram.*

[8] In the Lindland/Krogstie framework, this idea is taken further by the concept of feasible comprehension (Lindland et al., 1994; Krogstie et al., 1995b), which is achieved when the benefit of rooting out remaining misunderstandings does not exceed the cost of taking that effort.

*$H_{effectiveness}$: The accuracy of comprehension of a REA diagram is higher than the accuracy of comprehension of a non-REA diagram.*

*$H_{efficacy}$: The normalized accuracy of comprehension of a REA diagram is higher than the normalized accuracy of comprehension of a non-REA diagram.*

In all of the above hypotheses it is assumed that the REA and non-REA diagram are informationally equivalent and that the same comprehension task is applied to both types of diagram. The impact of these requirements on the design of the experiment is discussed further on in this section.

### 3.2. Selection of Participants

The experimental participants were 30 graduate business administration students enrolled in a master-level AIS course. Prior to the experiment the students were introduced to semantic modeling of accounting systems using the ER model. They were taught the basic principles of the REA accounting model.[9] They also learned how to instantiate the Basic REA Template. As part of the course exercises the students were required to analyze diagrammatic conceptual schemas of various kinds of transaction cycles for different types of companies, answering questions similar to the comprehension questions used in the experiment. Some of these diagrams were constructed using the Basic REA Template; others were not or instantiated only parts of the generic REA pattern. The modeling formalism was in all cases the ER model.

During the course, AIS was mainly studied from a system end-user perspective. The students were forced into the roles of accountants and auditors that need to work with AIS conceptual schemas in order to validate schemas with respect to end-user or business requirements (e.g. business rules) and to analyze the modeled business processes.. As in Kim and March (1995) we distinguish between these roles, describing essentially a passive way of model use, and more active roles assumed by modelers (e.g. information analysts) and system developers. Given the selection of participants, the comprehension task must reflect the model usage that is typical for the population under study (i.e. accountants, auditors, controllers, and business analysts).

### 3.3. Treatments and Experimental Design

The factor under investigation is the use of the REA model for developing a conceptual schema of a transaction cycle. As REA modeling of a transaction cycle involves instantiating the Basic REA Template, the treatments are the ‘administration’

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[9] The course didn’t touch upon advanced REA modeling concepts such as commitment patterns and type images as described in Geerts and McCarthy (2002).

of a REA diagram versus the 'administration' of an informationally equivalent non-REA diagram.[10]

Personal characteristics that are likely to have an impact on the ability to perform the comprehension task, like years of working experience, type of working experience, and number of MIS courses taken before, differed considerably amongst participants. In order to control for these differences, a within-subjects design was chosen. In such a design, each participant contributes an observation for each treatment.

The REA and non-REA treatments for each student relate to two different transaction cycles. The chosen transaction cycles, hereafter referred to as 'loan acquisition' and 'stock issuance', serve the same goal, i.e. acquiring funds for the company, and were similar in scope and structure. They were not studied before in the course, to avoid possible persistence effects. It could not be precluded, however, that one of them was intrinsically more comprehensible to the students than the other one. Therefore, to alleviate a potential instrumentation effect, four experimental objects were used, meaning that each of the transaction cycles was represented by a REA diagram and an informationally equivalent non-REA diagram.

To cancel out likely learning effects due to the use of the same underlying modeling formalism (the ER model) and similarities in the transaction cycles modeled, the transaction cycle (loan acquisition and stock issuance) and representation (non-REA diagram and REA diagram) were counterbalanced. The resulting experimental design is shown in Table 1. Participants were randomly allocated to two equal-size groups, hereafter referred to as group A and group B. Within each group, the order of the comprehension tasks was reversed for part of the students. For instance within group A part of the participants performed first the comprehension task required for the non-REA diagram of the loan acquisition cycle, and next the comprehension task required for the REA diagram of the stock issuance cycle, whereas this order was reversed for the other group A members.

**Table 1.** Experimental design

| **Type of diagram** | *non-REA* | | *REA* | |
|---|---|---|---|---|
| **Transaction cycle** | *Loan acquisition* | *Stock issuance* | *Loan acquisition* | *Stock issuance* |
| **Group** | Group A | Group B | Group B | Group A |

### 3.4. Instrumentation

The four experimental objects are included in Appendix A. They are conceptual schemas of financial transaction cycles showing the relevant entities, relationships and structural constraints. Since attributes, representing properties of entities and

[10] Given the proposition and operational hypotheses, an alternative view is to consider the use of a REA diagram as the treatment and the use of a non-REA diagram as the control. This view does not change the further design of the experiment, nor the type of analysis applied.

relationships, are not included, the diagrams should be considered as enterprise domain schemas, rather than conceptual data schemas.

As the research focused on pragmatic quality, all diagrams had to be syntactically correct,[11] meaning that all four diagrams obey the rules of the diagrammatic format of the ER model (Batini et al., 1992; Thalheim, 2000). The two diagrams used as objects for the REA treatment qualify also as REA diagrams in the sense that they are instantiations of the Basic REA Template, and hence obey the normative structure that is imposed by the REA model. They are representative outputs of a REA conceptual modeling exercise when applied to a financial transaction cycle. Moreover, they follow the usual placement conventions for REA diagrams.

Apart from syntactic correctness, the alternative diagrams of a transaction cycle had to be informationally equivalent to ensure a same level of semantic quality. If representations have the same information content, they are equally valid and complete with respect to the domain that is modeled, hence they are characterized by the same level of semantic quality (Lindland et al., 1994).

To ensure the information equivalence of the REA and non-REA diagram for the same transaction cycle, it was decided to construct first the REA diagram and next derive the non-REA diagram from it. The transformation from REA to non-REA aims at creating diagrams in which the REA pattern occurrence was no longer easily and quickly recognizable to the model user. The transformation was constrained, however, by the requirement of information equivalence, meaning that no information may be added or deleted from the REA diagram. It was decided therefore to apply the following modifications to a REA diagram to obtain an informationally equivalent non-REA diagram:

- Reify the economic duality relationship between the 'give' and 'take' event entities. The pairing of a resource outflow event ('give') with a resource inflow event ('take') is one of two essential structuring ideas that differentiates the REA accounting model from semantic models having no structuring orientation (Dunn and McCarthy, 1997). The reification of the economic duality relationship creates a new entity which is related by two new relationships to the dual event entities.
- No longer adhere to the usual placement conventions for REA diagrams. The readability guidelines for REA diagrams were deliberately violated to hide the underlying REA pattern occurrence.

The obtained non-REA diagrams continued to show some specific REA characteristics, in particular the other essential structuring idea that requires relating each event entity to a resource entity, an internal agent entity, and an external agent entity (Dunn and McCarthy, 1997). Loosening up this constraint would, however, result in less complete conceptual schemas (by omitting resources and/or agents), and

[11] Syntactic quality might have an impact on pragmatic quality, as hypothesized in Lindland et al. (1994). Therefore a same level of syntactic correctness for all experimental objects was required.

hence have a lower semantic quality, or are considerably more complex[12] (by reifying also the stock-flow and control relationships).
The REA diagrams for the two transaction cycles modeled were not completely symmetrical as in the experiment reported in Dunn and Gerard (2001). Some differences were deliberately injected in order to create a different pattern of correct answers to the comprehension questions and hence alleviate a possible maturation effect.

### 3.5. Design of Experimental Tasks

The experimental task involved answering 13 questions about the experimental object. The questionnaire was designed to reflect typical cases of schema validation or interpretation by domain experts or future system end-users. In order to validate or interpret a schema, it must be understood and it is exactly this understanding that the questions intended to test. The questions were also chosen such that the hypothesized enhanced understanding of REA diagrams as compared to non-REA diagrams could impact a subject's ability to provide the (correct) answer.

About half the questions were binary questions requiring a "Yes" or "No" answer.[13] Either participants were asked if they agreed to some statement about a business rule that holds for the transaction cycle modeled, or they were asked about the completeness of the schema with respect to reality. An example in the first category is "*Is the conceptual model that is depicted in the diagram correct given that in reality each dividend payment transaction relates to exactly one stock issuance?*" An example of the second category is "*Is the transaction cycle that is modeled in the diagram complete in the sense that for every business activity there is an employee that can be hold accountable?*" These questions reflect typical problems to be solved during schema validation.

The other questions were of the open kind and assessed a basic understanding of the model as can be required from accountants or auditors when analyzing business process models. They ranged from fundamental accounting issues like "*What economic duality is modeled in the diagram?*" to specific accounting system design questions like "*What entity type plays a central role when integrating this diagram with other diagrams representing other transaction cycles?*". These questions require interpreting the schema based on prior (though general) accounting domain knowledge, financial process knowledge, and accounting system design knowledge. They do not aim at schema validation as no statement on the reality that is modeled is provided.

The questions were formulated such that they were identical for the non-REA and REA diagrams of a same transaction cycle. Only the questions related to validity

[12] Empirical research has shown that the size and structural complexity of ER diagrams (basically in terms of number of entities and number of relationships) is related to their understandability (Genero et al., 2002; 2003).

[13] To prevent guessing, a negative score was associated to a wrong answer. Students were motivated to perform well in the experiment by giving them course credits depending on their score.

checking and resolution of business rule origin (three questions per questionnaire) needed some rephrasing in function of the financial transaction cycle modeled.

### 3.6. Operational Procedures

The experiment was organized as an individual class room exercise for which credits could be earned (as part of the final examination). At the start of the experiment, each subject was randomly allocated to a group and received the experimental materials for the first experimental run of the within-subjects experiment. When a participant finished the first comprehension task, all experimental materials including the answers to the questions were handed in and the materials required for the second part of the experiment were given to the participant. Participants could take whatever time they thought was necessary (within reasonable limits determined by practical considerations such as the duration of a typical course session). During the experiment, the student comprehension times (i.e., time between receiving the experimental materials of a run and handing in the answers) were measured by the experimenters.

After the experiment, the answers were corrected by the course teacher and double-checked by the experimenters. The answer to a binary question was considered correct if the appropriate choice between “Yes” and “No” was made. In case the wrong choice was made or no answer was given, the answer was considered incorrect. The answer to an open ended question was compared to a model answer, that contained the right solution to the problem presented. Only if this solution was found, the question was considered as being correctly answered.

## 4. Data Analysis and Interpretation

In this section the data collected from the experiment (included in Appendix B) are described and the hypotheses are tested. Descriptive statistics (mean, median and standard deviation) for comprehension time, accuracy of comprehension, and normalized accuracy are shown in Table 2. The sample size in each cell is 30.

**Table 2.** Descriptive statistics by treatment

| | | *REA* | *non-REA* |
|---|---|---|---|
| **Time (minutes)** | Mean | 24.13 | 27.33 |
| | Median | 25.50 | 28.00 |
| | Standard Deviation | 6.329 | 5.467 |
| **Accuracy** | Mean | 0.6512 | 0.5666 |
| | Median | 0.6538 | 0.5384 |
| | Standard Deviation | 0.1710 | 0.1984 |
| **Normalized Accuracy** | Mean | 0.0293 | 0.0217 |
| | Median | 0.0281 | 0.0202 |
| | Standard Deviation | 0.0116 | 0.0088 |

### 4.1. Hypothesis Testing

Given the relatively small sample size it was decided to use the nonparametric Wilcoxon Signed Rank Test.[14] The results of the hypothesis testing are summarized in Table 3.

**Table 3.** Results of Wilcoxon Signed Rank Test

| | z | significance (1-tailed) |
|---|---|---|
| Time REA < Time non-REA | -1.739 | 0.041 |
| Accuracy REA > Accuracy non-REA | -3.057 | 0.001 |
| Normalized Accuracy REA > Normalized Accuracy non-REA | -2.520 | 0.006 |

The results indicate that $H_{effectiveness}$ is supported ($p < 0.001$), meaning that the accuracy of comprehension is significantly higher if a REA diagram is used instead of a non-REA diagram. The difference in comprehension time is, however, only marginally significant ($p < 0.041$)[15]. Based on the experimental data it cannot be concluded that REA diagrams are significantly faster understood than non-REA diagrams. Therefore hypothesis $H_{efficiency}$ is not supported.

The difference in normalized accuracy scores between the two types of diagram is also significant ($p < 0.006$) and therefore $H_{efficacy}$ is supported.[16] So even when the trade-off 'more accurate comprehension versus faster comprehension' is in play (or in terms of the experimental tasks 'sacrificing correctness of answers for speed of answering'), the participants scored better when given a REA diagram. This result indicates overall efficacy of the REA model / REA modeling with respect to the user comprehension of diagrammatic conceptual schemas of transaction cycles.

### 4.2. Posttests of Confounding Effects

Counterbalancing diagram type (non-REA or REA) and transaction cycle alleviates possible learning and maturation 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) was administered first. Next the

[14] Similar results were obtained using the parametric Paired Samples t-test.

[15] The generally accepted significance cut-off of 0.05 (i.e. $\alpha = 5.0$ %) is applied for two-tailed tests. For one-tailed tests a significance cut-off of 0.025 (i.e. $\alpha = 2.5$ %) is common.

[16] This result comes as no surprise as in the only experiment we know of where the same three measures were used, the difference in normalized accuracy scores was significant whenever the difference in accuracy was significant, but not the difference in time (see Bodart et al. (2001)). The information provided by the normalized accuracy measure is, however, not redundant as in that experiment there was also a case where the difference in normalized accuracy was significant whereas no significant results were found for accuracy and time.

nonparametric Mann-Witney u-test[17] was used to evaluate differences in median comprehension times, accuracy scores, and normalized accuracy scores between the group of participants that received a non-REA diagram first and next a REA diagram (16 participants) and the group that started with a REA diagram and continued with a non-REA diagram (14 participants). Results are shown in Table 4.[18]

**Table 4.** Results of Mann-Witney u-test for effect of experimental run

| | Mean 1st run | Mean 2nd run | z | significance (2-tailed) |
|---|---|---|---|---|
| **Time non-REA** | 30.88 | 23.29 | -3.743 | <0.000 |
| **Time REA** | 28.21 | 20.56 | -3.457 | <0.000 |
| **Accuracy non-REA** | 0.51 | 0.64 | -1.722 | 0.093 |
| **Accuracy REA** | 0.67 | 0.64 | -0.420 | 0.697 |
| **Normalized Accuracy non-REA** | 0.02 | 0.03 | -3.413 | 0.001 |
| **Normalized Accuracy REA** | 0.03 | 0.03 | -1.871 | 0.061 |

The analysis shows that for the same type of diagram comprehension times are lower in the second experimental run. The accuracy of comprehension is not significantly different, except for the non-REA diagrams. when measured with the normalized accuracy measure. If it is assumed that participants have learned from their task performed during the first experimental run, then the effect of this learning is mainly limited to the efficiency dimension of user comprehension. Learning did in general not improve the accuracy of comprehension. The exception is the understanding of the non-REA diagrams in the second experimental run. This understanding is significantly better than the understanding of the non-REA diagrams during the first run, at least according to the normalized accuracy measure. A possible explanation of this differential learning rate is that participants that were confronted with a REA diagram in the first phase of the experiment might find it easier to recognize the hidden REA pattern occurrence in the non-REA diagram they received next. They therefore score better than the participants that started with a non-REA diagram.[19] As this effect of learning on normalized accuracy only holds for the non-REA diagram, it plays against the hypothesis $H_{efficacy}$, which was supported

[17] Similar results were obtained when the parametric Independent Samples t-test was applied.

[18] Results of between-groups tests should, however, be interpreted with caution as differences in human capability to perform the experimental task are no longer controlled for.

[19] Another (and perhaps more plausible) explanation is that for both types of diagram the comprehension time is significantly lower in the second run (because of a learning effect), whereas the accuracy score is not. As normalized accuracy is the ratio of accuracy to time, a decrease in time combined with constant accuracy scores normally results in an increase in the normalized accuracy score. This increase is significant for the non-REA diagrams ($p < 0.001$) as there also seems to be a marginally significant increase in the accuracy score between the first and second run ($p < 0.093$). For the REA diagrams there was no such improvement in accuracy scores ($p < 0.697$), which might explain why the difference in normalized accuracy for REA diagrams between the first and second run is less significant ($p < 0.061$) than with the non-REA diagrams.

by the experimental results. We therefore do not consider it as a serious threat to the validity of our study.

Because of the demonstration of a learning effect for comprehension time, it was decided to compare the participants' comprehension times for non-REA and REA diagrams, both before and after the learning took place. Tables 5 and 6 show test results respectively before learning (taking into account the observations of the first run) and after learning (using the observations obtained in the second run). Similar results were found in the within-groups analysis with counterbalancing (i.e. hypothesis $H_{efficiency}$ is not supported). So even before the learning takes place, there is no significant difference in comprehension time between the two treatments ($p < 0.086$).

**Table 5.** Result of Mann-Witney u-test for differences in comprehension time before learning

| | Mean non-REA | Mean REA | z | significance (2-tailed) |
|---|---|---|---|---|
| **Time** | 30.88 | 28.21 | -1.719 | 0.086 |

**Table 6.** Result of Mann-Witney u-test for differences in comprehension time after learning

| | Mean non-REA | Mean REA | z | significance (2-tailed) |
|---|---|---|---|---|
| **Time** | 23.29 | 20.56 | -1.209 | 0.227 |

Similar analysis was carried out to investigate possible differences in understanding that could be caused by the transaction cycle modeled. Here only one significant difference in performance was found between the diagrams for 'loan acquisition' and 'stock issuance'. It took significantly more time to understand the non-REA diagram of the loan acquisition cycle than the non-REA diagram of the stock issuance cycle ($Mean_{loan}$= 29.40, $Mean_{stock}$= 25.27, Mann-Witney u-test: $z = -2.149$, significance: $p < 0.032$). As the results of the other tests were not significant, it is unlikely that the loan acquisition cycle is inherently less comprehensible than the stock issuance cycle.

## 5. Conclusions

This paper reports upon an empirical study that evaluated the pragmatic quality of REA diagrams. Guided by theoretical frameworks for conceptual modeling quality and practice-oriented models for method evaluation in the IS field, a laboratory experiment was organized to assess and compare the user understanding of REA diagrams with that of informationally equivalent ER diagrams that are not obtained through the instantiation of the Basic REA Template. The experimental results indicate that the comprehension of a REA diagram is better in the sense that it is more accurate. However, no difference was found in the time taken to understand the diagrams. Hence, REA modeling of accounting systems might prove to be effective and efficacious in terms of improved user comprehension, though no support for its efficiency was found.

The results obtained in this study should be used with caution. Although the experimental task was designed to reflect the schema understanding required by business users for validation and auditing tasks, the experimental results might be task-dependent. Moreover, the demand to compare only informationally equivalent diagrammatic representations did not allow testing the full strength of the REA model (i.e. the ER diagrams that were used as the basis of the comparison, for the purposes of the experiment called non-REA diagrams, still showed a number of REA-specific characteristics). Furthermore, the experimental objects used were limited in scope to a single transaction cycle, whereas many of the claims of the REA model relate to schema and view integration aspects. The experimental participants also studied the ER model first, before they were introduced to the REA model, which might introduce an order of learning effect that explains why the experiment, organized at the end of the course, showed a better comprehension of the REA diagrams.

The goal of this work was to contribute to a systematic evaluation of the REA model. Although a first, incomplete and far from perfect step has been taken, there are other (and perhaps more important) quality types to consider. The evaluation must also be done from other perspectives, using other criteria (e.g. perceptions, beliefs, and intentions), starting from other roles of model users and builders (e.g. information analysts, database designers, system developers), and focusing on other tasks (e.g. information retrieval tasks, model construction tasks, model integration tasks) than the ones used here. All of this is necessary before the REA model can be considered as a definitive benchmark to evaluate alternative (in particular newly proposed) accounting data models. Our future work will therefore include replications and extensions of the current experiment, with a focus on both pragmatic and (perceived) semantic quality, using both performance-based and perception-based variables in experimental settings that include both script creation and script interpretation tasks.

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# Appendix A

The experimental objects used in the study are shown in Figures A-1 till A-4.

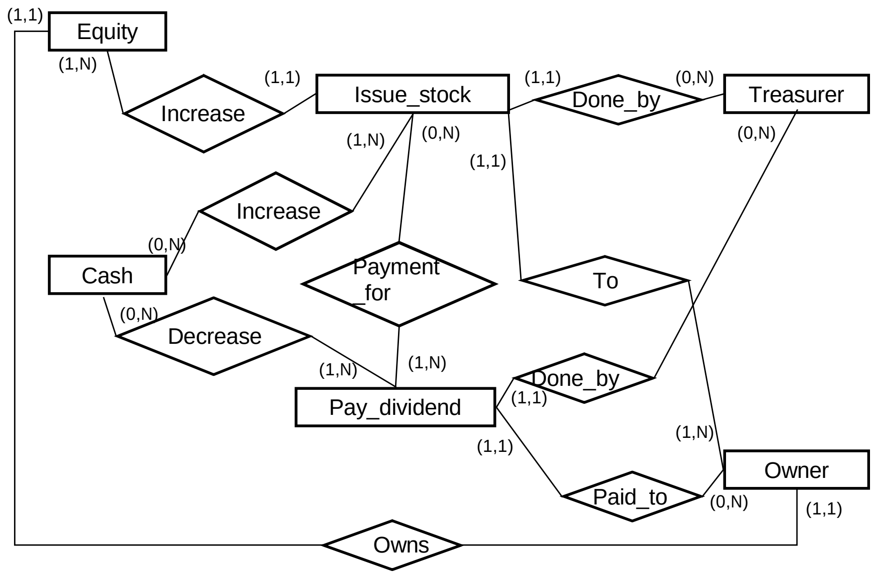


**Figure A-1.** REA diagram stock issuance

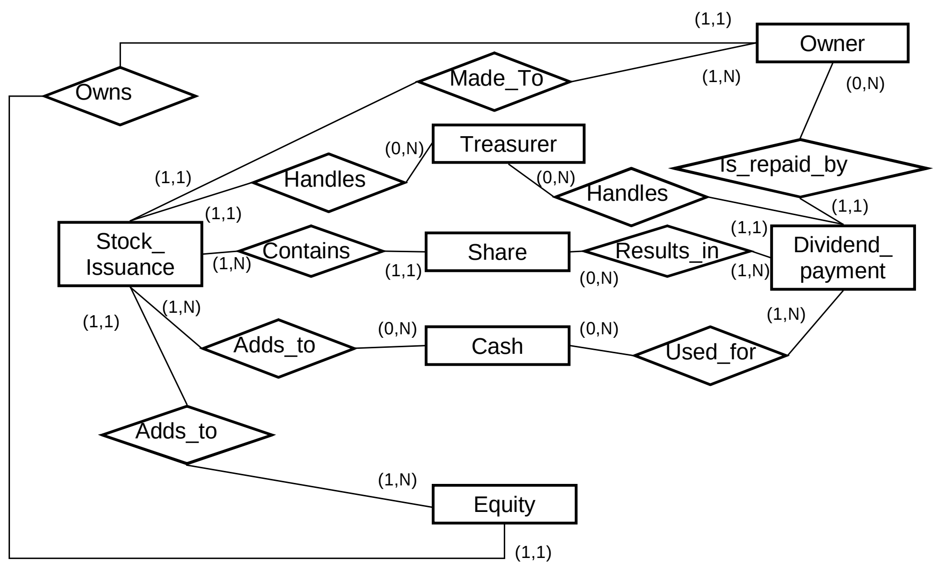


**Figure A-2.** non-REA diagram stock issuance

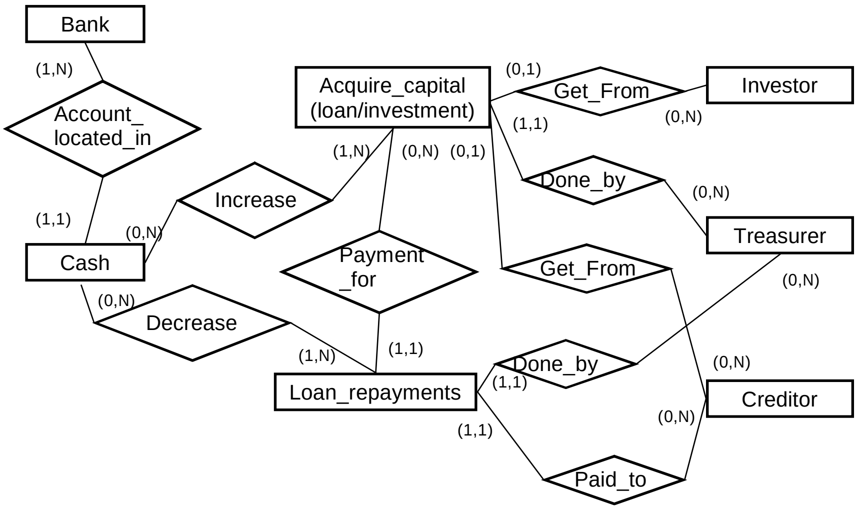


**Figure A-3.** REA diagram loan acquisition

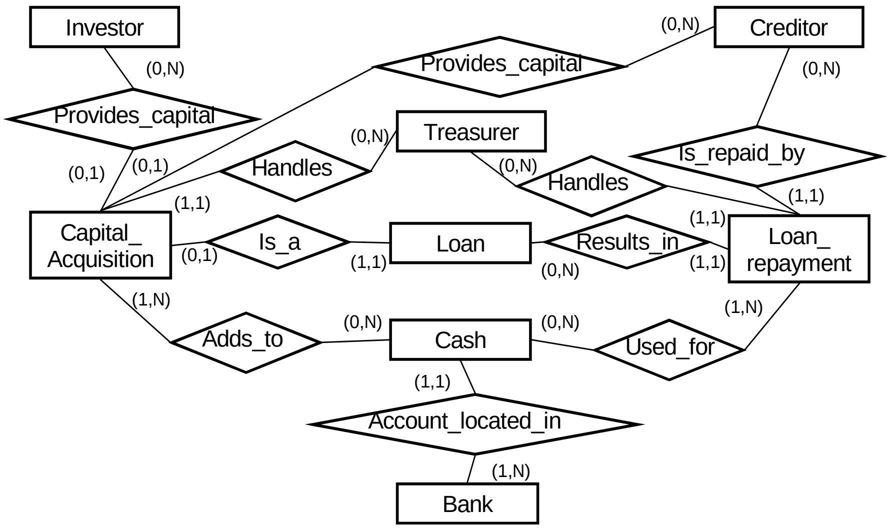


**Figure A-4.** non-REA diagram loan acquisition

## Appendix B

**Table B-1.** Experimental data

| | | non-REA | | | REA | | |
|---|---|---|---|---|---|---|---|
| Participant | Group | Time | Accuracy | Normalized Accuracy | Time | Accuracy | Normalized Accuracy |
| 1 | B | 26 | 0.61538 | 0.02367 | 17 | 0.84615 | 0.04977 |
| 2 | B | 28 | 0.53846 | 0.01923 | 22 | 0.92308 | 0.04196 |
| 3 | B | 30 | 0.61538 | 0.02051 | 19 | 0.76923 | 0.04049 |
| 4 | B | 30 | 0.38462 | 0.01282 | 27 | 0.38462 | 0.01425 |
| 5 | B | 33 | 0.53846 | 0.01632 | 23 | 0.84615 | 0.03679 |
| 6 | A | 23 | 0.46154 | 0.02007 | 25 | 0.38462 | 0.01538 |
| 7 | A | 22 | 0.84615 | 0.03846 | 27 | 0.76923 | 0.02849 |
| 8 | A | 19 | 0.69231 | 0.03644 | 29 | 0.84615 | 0.02918 |
| 9 | A | 30 | 0.76923 | 0.02564 | 31 | 0.69231 | 0.02233 |
| 10 | A | 28 | 0.53846 | 0.01923 | 13 | 0.61538 | 0.04734 |
| 11 | A | 28 | 0.46154 | 0.01648 | 26 | 0.46154 | 0.01775 |
| 12 | A | 29 | 0.84615 | 0.02918 | 21 | 0.84615 | 0.04029 |
| 13 | A | 30 | 0.38462 | 0.01282 | 12 | 0.46154 | 0.03846 |
| 14 | A | 30 | 0.76923 | 0.02564 | 15 | 0.76923 | 0.05128 |
| 15 | A | 31 | 0.15385 | 0.00496 | 23 | 0.38462 | 0.01672 |
| 16 | A | 33 | 0.15385 | 0.00466 | 13 | 0.53846 | 0.04142 |
| 17 | A | 33 | 0.46154 | 0.01399 | 27 | 0.53846 | 0.01994 |
| 18 | A | 33 | 0.53846 | 0.01632 | 26 | 0.53846 | 0.02071 |
| 19 | A | 34 | 0.69231 | 0.02036 | 28 | 0.84615 | 0.03022 |
| 20 | A | 38 | 0.38462 | 0.01012 | 17 | 0.46154 | 0.02715 |
| 21 | B | 24 | 0.84615 | 0.03526 | 18 | 0.84615 | 0.04701 |
| 22 | B | 19 | 0.53846 | 0.02834 | 23 | 0.69231 | 0.0301 |
| 23 | B | 28 | 0.53846 | 0.01923 | 25 | 0.69231 | 0.02769 |
| 24 | B | 24 | 0.61538 | 0.02564 | 28 | 0.61538 | 0.02198 |
| 25 | B | 33 | 0.92308 | 0.02797 | 28 | 0.92308 | 0.03297 |
| 26 | B | 16 | 0.38462 | 0.02404 | 30 | 0.53846 | 0.01795 |
| 27 | B | 21 | 0.61538 | 0.0293 | 30 | 0.61538 | 0.02051 |
| 28 | B | 18 | 0.30769 | 0.01709 | 32 | 0.46154 | 0.01442 |
| 29 | B | 27 | 0.53846 | 0.01994 | 33 | 0.53846 | 0.01632 |
| 30 | B | 22 | 0.84615 | 0.03846 | 36 | 0.69231 | 0.01923 |

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