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How Practitioners Perceive a Ternary Relationship in ER Conceptual Modeling

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A B S T R A C T

Conceptual modeling is well suited as a subject that constitutes the "core" of the Information Systems (IS) discipline and has grown in response to IS development. Several modeling grammars and methods have been studied extensively in the IS discipline. Previous studies, however, present deficiencies in research methods and even put forward contradictory results about the ternary relationship in conceptual modeling. For instance, some studies contend that the semantics of a binary relationship are better for novices, but others argue that a ternary relationship is better than three binary relationships when the association among three entity types clearly exists. The objective of this research is to acquire complete and accurate understanding of the ternary relationship, specifically to understand practitioners' modeling performance when utilizing either a ternary or binary relationship. To the best of our knowledge, no previous work clearly compares real-world modeler performance differences between binary and ternary representations. By investigating practitioners' understanding of ternary relationship and identifying practitioners' cognition, this research can broaden the perspective on conceptual modeling.

Keywords: Conceptual Data Models, Conceptual Model Grammars, Ternary Relationship, Entity Relationship Model, Empirical Research

Ⅰ. Introduction

Conceptual modeling is a complex task that performs during information systems (IS) analysis and development to represent certain semantics about real-world domains (Jones and Song, 2000; Song et al., 1993). Conceptual modeling is expressed using conceptual modeling grammars that offer constructs

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for representing real-world phenomena and rules defining how these constructs might be combined to represent focal domains (Shanks et al., 2010). One of the most widely accepted conceptual modeling grammars is the entity-relationship (ER) introduced by Chen (1976). ER modeling is the foundation of various analysis and design methodologies for the development of information systems. A key factor of success in the design of the model is the level to which it accurately reflects the real world environment it intends to represent. (Davies et al., 2006).

The original entity-relationship (ER) modeling grammar provides three constructs for representing phenomena in the world: entity, relationship, and attributes (Chen, 1976). Using them to build conceptual models of a domain is governed by certain rules: for example, two or more entities have to be connected via a relationship (Shanks et al., 2010). One of the most difficult problems in using ER modeling rules is the decision of whether to use a ternary relationship or multiple binary relationships to reflect complex entity relationship types (Shanks et al., 2003). Although the use of a ternary relationship is widely accepted in ER modeling, there is almost no formal analysis about ternary relationships (Hawryszkiewycz, 1991). In addition, there is argument revolving around whether it is preferable to apply a binary or ternary (*N*-ary) representation for relationships in ER models. Some argue for the superior ability of ternary (*N*-ary) modeling, because the ternary relationship reflects the true semantics of a given domain. Others, however, claim that binary modeling is better than ternary (*N*-ary), because binary modeling offers the simplest constructs for expressing information systems design (Mayer, 1989). However, studies that compare performance between a ternary and binary relationship in practice are few (Hawryszkiewycz, 1991; Jones and Song, 1996), if any, and studies used students as research subjects, who have little experience and insufficient domain knowledge about database modeling. Even several studies presented contradictory results about the relationships. In detail, while some research shows that users of a conceptual model have better performance, i.e., stronger understanding of domain semantics when expressed using the binary relationship than when expressed using the ternary relationship (Batra and Antony, 1994; Shanks et al., 2010), other studies indicate that a ternary relationship is superior to a binary relationship (Siau and Rossi, 2011).

Some studies regard inclusion of the ternary relationship as an ambiguity issue (Allen and March, 2012; Sears, 1986). They believe that configuration of the ternary relationship is an implicit expression rather than explicit (Song et al., 1993), and that clear meaning is achieved only using an explicit representation. In addition, different readers of a conceptual model can interpret meaning differently when a ternary relationship is used (Allen and March, 2012; Sears, 1986; Song et al., 1993).

Another limitation of previous studies comes from the use of students as research subjects. This has long been debated along with the wider discussion of generality, because the university circumstance is likely to be different in several major ways from organizational circumstance (Compeau et al., 2012). Sears (1986) contended that, “college students are likely to have less crystallized attitudes, less formulated senses of self, stronger cognitive skills, stronger tendencies to comply with authority, and more unstable peer group relationship” (p. 515) (Compeau et al., 2012; Rosemann et al., 2003). He further claimed that these differences may lead to flawed conclusions (cited in Compeau et al., 2012). Tolman (1959) expressed the most extreme view of this, “college sophomores are apparently not real people” (p. 7). The

」choice of a student sample, therefore, must be assessed against research goals and context. In the case of modeling, it is hard to assert that the majority of users of the conceptual model are students, even if they are learning modeling techniques from some courses. It is argued that actual research subjects should be practitioners who frequently embrace conceptual models as a tool to communicate with users (and developers), and to understand the business domain (Date, 2006). The majority of laboratory experiments in conceptual modeling studies, however, used student subjects (Compeau et al., 2012) and few studies used practitioners as research subjects.

The objective of this research is to provide a better way to recognize and understand the semantics between binary and ternary. In order to achieve this goal, we use practitioners who are experienced data modelers as research subjects. To the best of our knowledge, our study is the first attempt to use practitioners to investigate binary and ternary relationships. Practitioners who have embraced conceptual modeling can be actual users of the conceptual model, therefore, they are expected to give more accurate results that may better address various issues. In addition, a ternary relationship can reveal the true semantics of a given domain to practitioners who have a strong understanding of the domain (Hawryszkiewycz, 1991; Jones and Song, 1996; Simsion and Witt, 2004). This leads to the following hypothesis:

H: User of conceptual modeling diagrams better understand domain semantics when expressed using ternary relationships than when expressed using binary relationships.

To attain a more complete and accurate understanding of binary and ternary relationships, we perform an experiment using practitioners with considerable experience and sufficient domain knowledge about modeling. In addition, we offer the most plausible explanation by the result of experiment.

Ⅱ. Background Research

This section presents previous studies and related theory in this area. Terminology that is used throughout the paper is defined prior to proceeding to the body of the paper. Since some terms in this field can be interpreted differently, this will serve as a solid foundation for the ensuing discussion.

A *binary relationship* is a relationship of degree two. It is a relationship that contains two participating entities and takes the form of 1:1, 1:*M*, or *M*:*N*. A *ternary relationship* is a relationship of degree three. It is a relationship that contains three participating entities. Cardinalities for the ternary relationship takes the form of 1:1:1, 1:1:*M*, 1:*M*:*N* or *M*:*N*:*N*. The cardinality constraint of an entity in a ternary relationship is defined by a pair of two entity instances associated with the other single entity instance. For example, in a ternary relationship R(*X*, *Y*, *Z*) of cardinality *M*:*N*:1, for each pair of (*X*, *Y*) there is only one instance of *Z*; for each pair of (*X*, *Z*) there are *N* instances of *Y*; for each pair of (*Y*, *Z*) there are *M* instances of *X*.

2.1. Previous Research

Considering the *N*-ary relationship, the ternary relationship remains a problematic issue because there are several possible alternative ways to represent the relationship. Studies on the relationship between binary and ternary configurations in ER modeling are very few (Siau and Rossi, 2011). Although few research studied ternary relationship, they only focused on relationship cardinalities on ER Modeling (Song et al., 1993). Moreover, most of them simply deal with rules to translate an entity-relationship diagram (ERD) into a binary representation such as the decomposition of ERD into 4 Normal Form (Chung et al., 1981) or solutions to translate a ternary relationship into a set of binary relationship (Gemino and Wand, 2005).

Some experiments regarding a ternary relationship reveal that a ternary relationship should only be used when the association among three entity types cannot be represented by several binary relationships (Simsion and Witt, 2004) and argue that the semantics of a binary relationship are more easily recognized and understood than that of a ternary relationship, especially for novices (Allen and March, 2012; Batra and Davis, 1992; Fidell et al., 1996). In an experiment by Allen and March, they tested the assumption that users of a conceptual model understand domain semantics better when it is expressed using a binary relationship than when expressed using a ternary relationship. They tested thirty-three university students majoring in Information Systems as research subjects and found that the binary relationship is better than the ternary relationship. None of these studies, however, used practitioners, i.e., actual users, to compare performance differences between binary and ternary representations.

2.2. Theory of Ontological Clarity

It is important to determine which method of representation of real-world phenomena in a conceptual model enables humans to better understand the phenomena (Sears, 1986). There are two theories regarding such matters. The first is the ontological theory provided by Bunge (1977) and the second is the theory of ontological clarity proposed by Wand and Weber (1993). Both theories contend that conceptual model must be explicit to provide understanding and must not introduce a confounding meaning. Specifically, the theory of ontology clarity proclaims that when the constructs of conceptual modeling grammar exist in a bijective correspondence with the constructs of an ontology, models developed with that grammar will more effectively communicate meaning to users than models designed to use the grammar with ontological mappings that are either surjective or injective (Teorey et al., 1986). Within bijective correspondence, each construct in grammar is mapped to precisely one construct in the ontology and each construct in the ontology is mapped to one construct in the grammar. In surjective correspondence, multiple constructs in grammar are mapped to the same construct in the ontology or multiple constructs in the ontology are mapped to the same construct in grammar. Within injective correspondence, constructs in grammar have no corresponding construct in the ontology and vice versa.

In view of the conceptual modeling grammar, a ternary relationship introduces a strong confound, because in this view, the semantics of the ternary relationship are significantly more difficult to understand than are the semantics of the binary relationship (Allen and March, 2012). As with any relationship, an instance of a ternary relationship associates with exactly one instance of each of the related entities, the semantics of the ternary relationship and constraints, however, are complex (Fidell et al., 1996). This research questions the key argument that if a model fails to exhibit a one-to-one mapping between construct in the grammar and construct in the ontology (bijective correspondence), then users' understanding of the represented domain will suffer. Regarding the issue, Date (2003, p. 436) eschewed the distinction between an entity (thing) and a relationship (type of property of a thing), "In this writer's opinion, any approach that insists on making such a distinction is seriously flawed, because… the very same object can quite legitimately be regarded as an entity by some users and a relationship by others" (Cutrell and Guan, 2007; Shanks et al., 2010). Therefore, the theory of ontological clarity suggested by Wand and Weber (1993) needs to be verified to yield more reliable insight.

Ⅲ. Research Method

To test our hypothesis, we employed a laboratory experiment to: (a) control extraneous factors that might confound any impacts of alternative representations of a binary or ternary relationship on how well users comprehend conceptual models between the two relationships, and (b) obtained a sufficient number of participants for our research.

3.1. Design and Measures

The experiment used a between design, with different relationships, three binary or ternary relationships, manipulated between groups, such that each participant received either a ternary relationship model or three binary relationship model by random assignment and the questionnaire.

Determining a dependent variable is critical factor of the conceptual model, because in practice, users of a conceptual model might understand semantics from a diagram in consultation with others and the result of such contact is difficult to elicit the precise semantics of the model given to the users. To correctly measure how well the conceptual model delivered semantics to users and to eliminate as many confusing features as possible in considering this outcome, prior research has selected Mayer (1989)'s measures of performance based on recall, comprehension, and problem-solving as dependent variables (Bodart et al., 2001; Ericsson and Simon, 1993; Newell and Simon, 1972). These tasks perform as a proxy for how well users draw semantics from the conceptual model in practice (Shanks et al., 2010).

We selected problem-solving performance as the dependent variable, because compared to recall and comprehension performance, problem-solving performance conveys a superior index of a user's "deep" understanding of a domain (Bloom et al., 1956; Shanks et al., 2010). In other words, if users comprehend the domain better, they can better structure their problem space, and better structure problem spaces, in turn, facilitating problem solving (Shanks et al., 2010). We measured how well users understood the model via problem-solution accuracy. We also used one additional measure of performance: time taken to offer a problem solution. If the conceptual model brings better domain semantics to experimental participants, they would solve the problem faster.

In addition, this research performed a study of cognitive process tracing to better recognize the cognitive behavior patterns of users of conceptual models and to provide an explanation of the results we acquired in our experiment. Cognitive process tracing is an accepted data collection method in Information Systems research and cognitive psychology (Sears, 1986). We collected data about the cognitive processes of experimental participants using a verbal protocol. A verbal protocol technique needs individuals to verbalize their thoughts when they perform a task (Erickson and Mattson, 1981) and is used to compare cognitive search activities between two groups (Ericsson and Simon, 1984; Sears, 1986). It is based on the assumption that humans determinedly form a representation of a problem and their specific problem-solving strategies when they answer a question (Ericsson and Simon, 1984; Sears, 1986). In this research, we use a simultaneous verbal protocol technique. Experimental participants are asked to think aloud during the problem-solving stage, thus giving researchers direct access to their thought processes (Erickson and Mattson, 1981; McKee and Rodgers, 1992). We focused on: (a) understanding the cognitive behavior of participants when they performed the tasks in which an important difference exists and (b) providing a detailed explanation about these results.

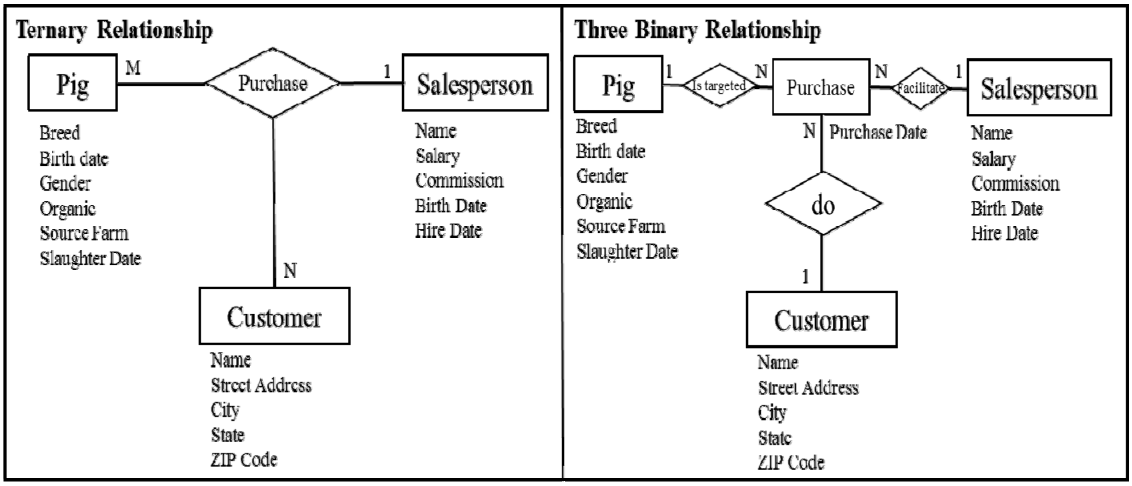
3.2. Materials

Four sets of materials are used in the experiment. The first set of materials comprises a personal profile questionnaire to gather information about participants' academic qualifications, the industry in which they worked, the number of years they have spent in the database field, the number of years they have spent in modeling, the most frequently used conceptual modeling techniques and tools, and the most significant objective of using conceptual modeling. We use these materials to determine whether the participants who received the different treatments had similar education level, qualifications, work experience, etc.

The second set of materials is a summary of the ER diagram symbols that are presented in the diagrams. This is prepared to inform participants of the meaning and usage of each ER diagram symbol. Note that to increase our contribution to conceptual modeling practice, we decided to base our study on the ER approach to conceptual modeling, because this approach has been generally used in practice (Parsons and Cole, 2005; Sears, 1986; Shanks et al., 2003). Additionally, we did a preliminary interview with several practitioners to decide which modeling technique to use for the script. More than 90% of practitioners answered that they have learned and used the ER diagram as a conceptual modeling technique.

The third set of materials consists of two ER diagrams of three binary and ternary relationships. Research subjects were told that Wasatch Pork Distributors (WPD) have been required to track which pigs were involved in purchases made by each of its customers. To increase the reliability of the experiment, we used the same models proposed by Allen and March (Allen and March, 2012). We, however, adopted ER-diagrams instead of Unified Modeling Language (UML) because the majority (90%) of our experimental subjects have used the ER-Diagram approach. <Figure 1> presents the ER-diagrams used in our experiment. The first diagram contains a ternary relationship model (i.e., an implicit representation of model). The second diagram has three binary relationships instead of one ternary relationship (i.e., an explicit representation of model). Each diagram expresses similar, though not identical, domain semantics.

The fourth set of materials comprise nine problem-solving questions per each model, to which participants should give a response of "yes," or "no." <Table 1> provides the questionnaires of the each model suggested by Allen and March (2012). We selected them to: (a) provide good coverage of the different semantics represented in the ER diagrams, (b) have different levels of complexity, and (c) make the participants use the ER diagrams to answer correctly rather than they rely on their domain knowledge. Some questions constituted baseline questions and they were chosen to deliver us with some belief that any performance difference between the two groups would be attributed to the experimental treatment rather than other confounding factors.



<Figure 1> Ternary vs. Three Binary Relationships Models (Source: Allen and March, A Research Note on Representing Part-Whole Relations in Conceptual Modeling, p. 956, <Figure 5>, "Experiment 1," © 2012, Regents of the University of Minnesota)

<Table 1> Questionnaires of Each Model

Question	Ternary Relationship Answer	Three Binary Relationship Answer
1. Can a customer purchase a pig without a salesperson?	No	No
2. Can two customers be involved in a single purchase?	No	No
3. Can portions of the same pig be purchased by more than one customer?	Yes	Yes
4. Can two different salespersons sell portions of the same pig to different customers?	Yes	Yes
5. Can two different salespersons sell portions of the same pig to the same customer?	No	Yes
6. Can a customer make a single purchase for portions of an organic pig and for portions of one that is not organic?	No	No
7. Can a single purchase involve two salespersons?	No	No
8. Can a customer make two different purchases for portions of the same pig from the same salesperson?	No	Yes
9. Cuts from a particular pig have been found to be contaminated. Can responsibility for the sale of portions of that pig to that customer be limited to a single salesperson?	Yes	No

Note: Source: Allen and March, A Research Note on Representing Part-Whole Relations in Conceptual Modeling, p. 956, <Figure 5>, "Experiment 1," © 2012, Regents of the University of Minnesota

3.3. Participants

This study selects not a student but a practitioner as a research subject. The use of students as research subject has been disputed along with the discussion of generalizability because of the low external validity. Sears (1986) contended that, "college students are likely to have less crystallized attitudes, less-formulated senses of self, stronger cognitive skills, stronger tendencies to comply with authority, and more unstable peer group relationships" (p. 515). He further claimed that these differences may lead to flawed conclusions (cited in Compeau, 2012). In addition, Davis et al. (2005) stated that it is hard to assert that the major user of conceptual modeling is the student, even if he or she learned some courses related to Information Systems Therefore, we select practitioners as research subjects.

Participants in the experiment were forty individuals (practitioners) working in various industries and willing to help us with the experiment. All of them have at least a five-year database career as a database manager and/or administrator. Protocol analysis was also performed for selected six participants who have at least ten years modeling experience. Davis et al. (2005) presented the top six most commonly used modeling techniques stratified according to the years of modeling experience of the practitioners (Date, 2006). The results of the study showed that a significant increase in usage from the 0-3 years level to the 4-10 years level of experience. Accordingly, we selected participants who fit the above category. All participants acted as surrogate application system stakeholders in the experiment, because they: (a) generate a conceptual model, (b) communicate with developers and end users, and (c) assist analysts to recognize a domain. <Table 2> presents demographic data about the participants. All of them have a technical information system role in their organization and had at least a bachelor's degree.

<Table 2> Participant Demographic Data

Industry Sector	Ternary Relationship	Three Binary Relationships	Total
Electrical and communication	7	5	12
Distribution Industry	1	2	3
IT/IT Consulting	10	11	21
Public Enterprise, Public Sector	1		1
Etc.	1	2	3
Time in Database Field	**Ternary Relationship**	**Three Binary Relationships**	**Total**
1-5 Year	4	4	8
6-10 Year	14	15	29
11-15 Year	2	1	3
Time in Modeling	**Ternary Relationship**	**Three Binary Relationships**	**Total**
1-5 Year	15	15	30
6-10 Year	4	5	9
11-15 Year	1		1

3.4. Procedures

Participants were first assigned randomly to one of the two treatments (20 per treatment) for three binary relationships or a ternary relationship. Next, they were given a consent form and a questionnaire to acquire demographic and experiential information. The task they were to perform and the nature of the experiments was also explained. Then they were given the document that explained the ER diagram symbols. If they have some questions about symbols and examples, we provided answers to the questions. This procedure continued until they felt confident about the ER-diagrams. Participants were allowed to refer to the ER diagram symbol documents during the experiment. When participants were ready to start, they were given either three binary relationships or a ternary relationship ER-diagram which reflects the Wasatch pork distributors. Participants then undertook the problem-solving tasks and the time they took to answer each problem-solving question was recorded. Finally, when participants completed the questions, they were thanked and dismissed. On average, it took about 30 minutes to complete the questionnaires.

In addition, six subjects were randomly selected for protocol analysis. They were asked to speak aloud as they attempted to solve each problem-solving question and their verbalizations were tape-recorded. The detailed process was similar to the procedure for the non-protocol analysis participants. Protocol analysis was, however, performed separately with research assistants. During the experiment, if periods of silence occurred, research assistants reminded them to "speak aloud" to explain their cognitive behaviors. Each assistant individually recorded the voice of each participant and notes were prepared based on participant reactions, questions, and approaches to each problem-solving question.

Ⅳ. Results

The results were analyzed at four levels. First, scores for individual items on the problem-solving measure were calculated. Second, reliability analysis on the problem solving was performed. Third, the hypothesis was tested by performing statistical analysis to understand treatment differences in the scores for the problem-solving and time. Fourth, the qualitative data was analyzed to discover how the two treatment groups differed in terms of their performance on the problem-solving tasks.

4.1. Data Scoring

Scores were calculated as follows. One mark was given if the answer ("yes" or "no") was correct; zero was given if a participants' answer was incorrect or left blank. Participants were encouraged not to answer the question by guessing. One participant's answer sheet had two blank answers.

For protocol analysis, a coding scheme was established based on the problem-solving literature (McKee and Rodgers, 1992) and previous research about conceptual modeling (Batra et al., 1990; Shanks et al., 2010). In this study, considering the volume of data, episodes were selected for use as the unit of analysis. An episode is a small self-contained phase of highly organized activity (McKee and Rodgers, 1992). The assumption of the coding scheme is that a concurrent verbal protocol can indicate the problem space in which the subject is currently looking for (Jones and Song, 2000; McKee and Rodgers, 1992).

According to what subjects stated during each episode, it was classified as one of the following.

- *Understanding Question Level* : During this step, the subject would read the question, consider the requirements and identify assumptions. The focus at this stage is on developing a reasonable understanding of the problem.

- *Recognizing Level* : At this step, the subject would focus on some specific parts of the model establishing connections with the key concept of the question. This would initiate the appropriate knowledge in a subject's repertoire.
- *Representing Level* : The representation step consists of verifying semantics of symbols in the model and developing answers. During this stage, the subjects would re-read the question or the summary of the ER diagram symbol. This would activate operationalization of the subject's deep understanding of the model into a conceptual data representation using the ER diagram.
- *Evaluating Level* : This step includes confirmation of the answer to ensure it satisfies the user requirements or selection of alternative answers.

4.2. Reliability Assessment

The reliability of the problem solving scores was checked. In the three binary relationship model, Cronbach alpha for the nine problem-solving questions was 0.73. In the ternary relationship model, Cronbach alpha for the nine problem-solving questions was 0.71. All Cronbach's alpha coefficients higher than 0.7, indicating good reliability. Deletion of any question generated no significant effect on the reliability score. In the light of those results, all questions were retained.

4.3. Quantitative Data Analysis

<Table 3> shows descriptive statistics for the total accuracy of problem solving and total time. An independent samples multivariate *t*-test was used to compare the user performance of the ternary and three binary relationship model groups, because the total accuracy and time scores for the nine problem solving questions are relatively uncorrelated (Shanks et al., 2010; Simsion and Witt, 2004).

Research subjects' overall performance for the ternary relationship was slightly lower than research subjects' performance for the three binary diagram. Subjects performed almost 3.1 percent better with a binary-only treatment than they do with the ternary treatment, correctly answering, on average 6.6 as compared to 6.4 of the total nine questions, respectively. On a question-by-question basis, subjects perform better on the binary treatment for questions, 1, 5, and 8. Subjects, however, perform better on the ternary treatment for questions 4 and 9.

The average time taken by participants was 23.4 minutes for the ternary relationship model and 22.2 minutes for the three binary relationship model. The difference of time taken between two groups was not statistically significant using a two-tailed *t*-test

<Table 3> Descriptive Statistics for Dependent Measures

Relationship Type		Mean	Std. Deviation
Ternary Relationship (n = 20)	Problem Solving	0.64	0.23
	Time	23.4	1.92
Three Binary Relationship (n = 20)	Problem Solving	0.66	0.23
	Time	22.2	1.65
Total (n = 40)	Problem Solving	0.65	0.23
	Time	22.8	1.78

(t = -1.26, df = 38, p = 0.267).

<Table 4> presents the difference for each question between the two groups in terms of problem-solving accuracy. The difference for each question between the two groups was not statistically significant using a univariate t-test, except for question 5 ($p < 0.01$), and the difference for all questions between the two groups was not statistically significant using a two-tailed t-test (t = 0.298, df = 38, p = 0.786).

In summary, strong support was acquired for the hypothesis based on problem-solving performance. If the ternary relationship is a hindrance factor in human performance in problem-solving tasks using a conceptual model, we would expect to see a majority of statistically significant results among all the tests conducted. The results, however, show that the ternary relationship is not a prominent factor that impedes human performance.

4.4. Qualitative Data Analysis

Qualitative data analysis was performed to gain a deeper understanding that would be difficult to acquire through quantitative analysis about the effect of treatment. The purpose of this analysis was to gather a more in-depth understanding of participants' thought processes when they tried to solve the problems.

The protocol data was analyzed in two steps. First, the average time that participants spent in each of the four cognitive behavior categories (as shown in Data Scoring section) was compared. Deciding in which category the main differences occurred was

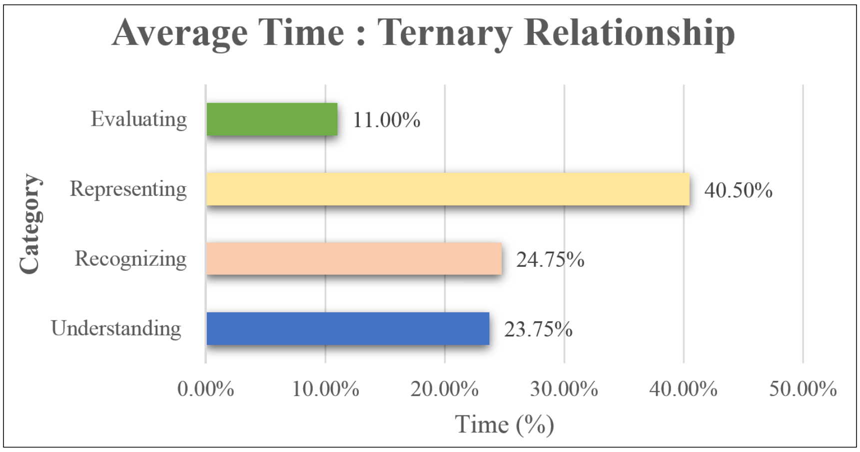
<Table 4> Accuracy Performance for Problem-Solving Question

Relationship Type				*t*-test for Equality of Means		
Items	Overload	Mean	Std. Deviation	*t*	Sig. (2-tailed)	Mean Difference
1	Ternary Relationship	0.75	0.444	-0.777	0.442	-0.100
	Three Binary Relationship	0.85	0.366			
2	Ternary Relationship	0.85	0.366	0.000	1.000	0.000
	Three Binary Relationship	0.85	0.366			
3	Ternary Relationship	0.80	00.410	0.000	1.000	0.000
	Three Binary Relationship	0.80	0.410			
4	Ternary Relationship	0.85	0.366	1.125	0.267	0.150
	Three Binary Relationship	0.70	0.470			
5	Ternary Relationship	0.45	0.510	-2.847	0.007***	-0.400
	Three Binary Relationship	0.85	0.366			
6	Ternary Relationship	0.20	0.410	0.000	1.000	0.000
	Three Binary Relationship	0.20	0.410			
7	Ternary Relationship	0.85	0.366	0.000	1.000	0.000
	Three Binary Relationship	0.85	0.366			
8	Ternary Relationship	0.40	0.503	-0.312	0.757	-0.050
	Three Binary Relationship	045	0.510			
9	Ternary Relationship	0.60	0.503	1.594	0.119	0.250
	Three Binary Relationship	0.35	0.489			

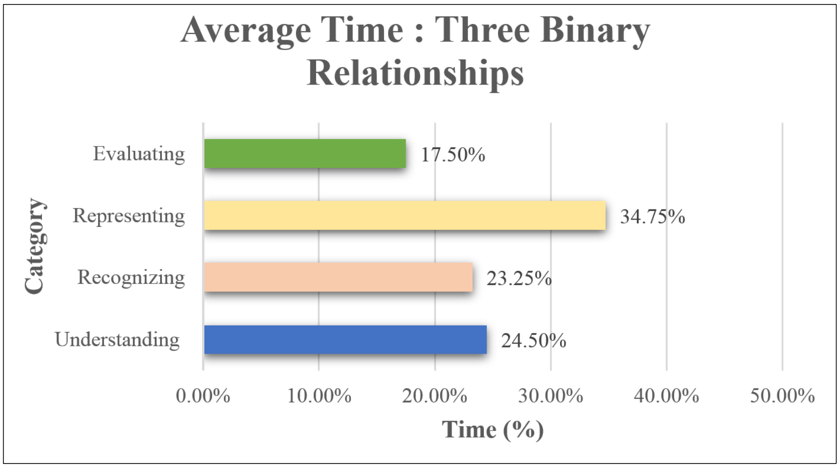
Note: *p < 0.1, **p < 0.05, ***p < 0.01

considered as one result indicator. Second, the total number of switches between each of the four cognitive behavior categories were compared. These results were considered as indicators for the sequence pattern in the cognitive process.

The average time that participants spent in each cognitive behavior category is presented in <Figures 2 and 3>. Participants who received the ternary relationship model took 25.1 minutes to complete all nine problem-solving questions and those who received the three binary relationship model took 23.9 minutes. In both models, the data suggested that although there was no notable difference in the total time taken between ternary model and three binary relationship model, there was a difference in the way the completion time represented category. In detail, participants who received the ternary relationship model spent 40.5 percent of their time in verifying semantics of the symbols in the model and developing solutions compared to 34.75 percent for participants who received the three binary relationship model. As mentioned before, during this step, the



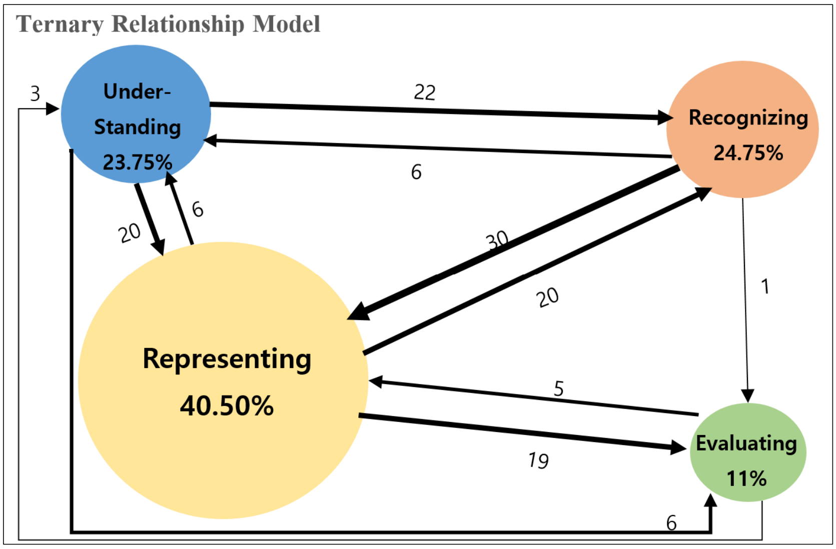
<Figure 2> Average Time Spent in Each Behavior Category (Ternary Relationship)



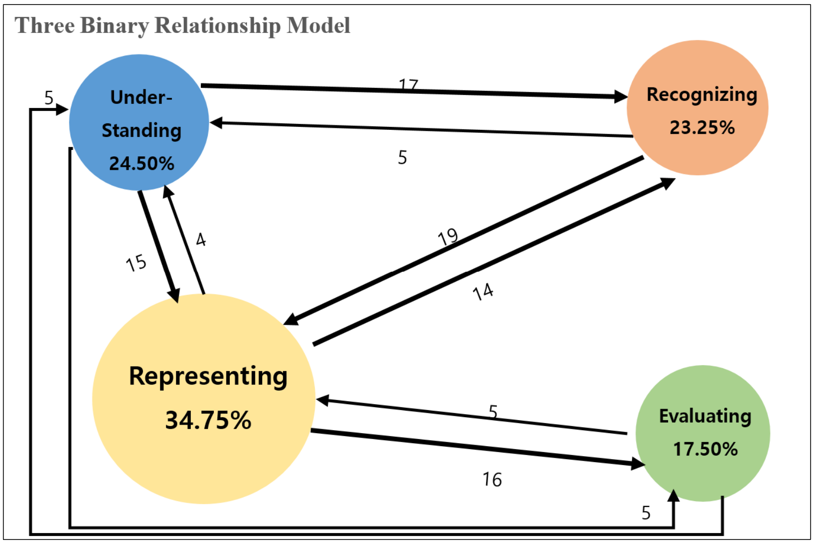
<Figure 3> Average Time Spent in Each Behavior Category (Three Binary Relationships)

subjects would re-read the question or the summary of the ER diagram symbol, indicating that participants who received the ternary relationship model had a hard time to dealing with the semantics of the symbols. This result suggests that the ternary relationship model requires participants to develop a more thorough understanding than the three binary relationship model.

In addition, participants who got the ternary relationship model spent 11 percent of their time verifying semantics of the symbols in the model and finding solutions compared to 17.5 percent for participants



<Figure 4> Total Number of Transitions between Each Behavior in the Ternary Relationship Model



<Figure 5> Total Number of Transitions between Each Behavior in the Ternary Relationship Model

who got the three binary relationship model. However, participants who received the ternary relationship model spent less of their time in evaluation of the solution, indicating that they had some confidence in their answer. As a result, although the ternary relationship model may promote more representation and recognition, once the answer was obtained, there was some assurance that a proper solution would follow.

The sequential dependencies between the four behavior categories are depicted in <Figures 4 and 5>. The numbers below the dependency arrows are the total number of transitions between two categories. The intensity of the dependency is represented by arrow thickness. In the case of two models, the pattern and total number of transitions are similar. In detail, the most common sequence for participants, regardless of the type of model, was in recognizing and representing the model, indicating that participants focus on particular parts related to certain questions and then try to improve and verify the answers by examining the model itself and using their knowledge.

Participants who received the ternary relationship model had more transition activity for the recognizing and representing model segment of the cognitive behavior categories. For instance, the ternary relationship model had 42 transitions in 37 transitions out of the recognizing model segment cognitive behavior category compared to 31 transitions in and 24 transitions out for participants who received the three binary relationship model. They also had 55 transitions in and 45 transitions out of the representing model segment compared to and 39 transitions in and 34 transitions out. These results indicate that participants who got the ternary relationship model focused more on finding connections with the key concept of the question and verifying semantics of symbols in the model and developing solutions. These results indicate that participants who had the ternary relationship model would struggle more to verify the model when trying to match the proper model section.

V. Discussion

This section draws conclusion from the research, and presents limitations and future research directions.

5.1. Conclusion

In this study, the research concept was deliberately conceptualized and an experiment hypothesis was designed based on in-depth examination of existing studies and experiments. The research hypothesis was that the ternary relationship does not result in inferior performance for practitioners when used in a conceptual model and was supported by our results. Based on this result, our study significantly contributes to data modeling studies in several respects, both in practice and research, because the research subjects were practitioners of the conceptual model. As such, they reflect persons that actually adopt the conceptual model to communicate with the end-users and to understand the target business domain (Date, 2006). In professional practice, the results of this research will broaden the perspective on usability in the context of the conceptual model, because the results indicate that a syntactically simpler model expressed by ternary relationships can be useful for the user when the user interprets the domain of model. Furthermore, the semantics expressed by ternary relationships is not significantly more difficult for the user than those expressed by three binary relationships. This research suggests that users need not be circumspect if they use the ternary relationship in conceptual modeling. For example, if modelers are concerned about whether to use the ternary relationship or not when they create a model, they can add the ternary relationship, because it does not result in inferior understanding to users.

For research, the study focused on the necessity of the ternary relationship. It has been recognized that ontological clarity is achieved only when the mapping between a set of conceptual modeling constructs and a set of ontological constructs is isomorphic. Based on this, the ternary relationship will undermine a user performance regarding ontological clarity (Tolman, 1959), because it is an implicit expression of model. In our experiment, however, a ternary relationship does not hinder the practitioner's understanding of the conceptual model. Therefore, Wand and Weber (1993)'s theory regarding ontological clarity should consider various actual human contexts such as background information, prior experience and level of understanding (Burton-Jones et al., 2005; Tolman, 1959).

5.2. Limitations and Future Research Directions

In this study, we used Wasatch pork distributors as a model domain, which was somewhat unfamiliar to users. As such, performing an experiment on different domains (e.g., familiar domains), such as a library domain (Bera et al., 2014), project-planning domain (Rosemann et al., 2003), or business domain (Allen and March, 2012) could be meaningful. Applying various degrees of domain familiarity may improve our understanding of how users apply past knowledge to resolve ambiguity and presumptions about whether the domain operates as they expected. Therefore, employing different degrees of domain familiarity (e.g., familiar vs. unfamiliar domains) to investigate the difference between various domain familiarities can detect the role of domain knowledge in terms of applying the ternary relationship. The authors encourage future research efforts to focus on acquiring an understanding of the effects of using different domains in conceptual modeling.

Like most cognitive process tracing research, our study was limited in range. Future research may use alternative research methods such as action research to test our hypothesis in a more realistic environment (Sears, 1986; Shanks et al., 2003) and techniques such as eye-tracking and brainwave analysis. The eye-tracking technique is a promising method in Information Systems and acquires much more detailed moment-by-moment observations (Cutrell and Guan, 2007). In other words, eye-tracking techniques can be a proxy for a users' attention when they read the model. In addition, brainwave analysis may provide further insights into unconscious attention, and primary- and secondary-process thinking when users are interpreting a model. Therefore, using other methods and techniques can provide more precise and insightful data regarding the cognitive aspects of human performance.

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