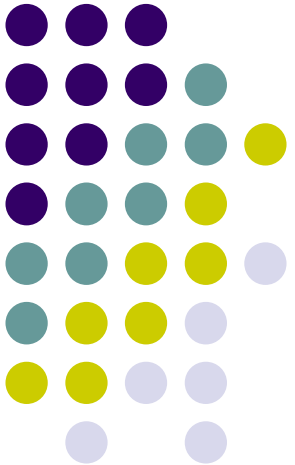
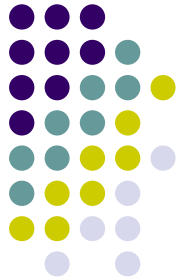
Accounting ontology and conceptual modeling

Geert Poels



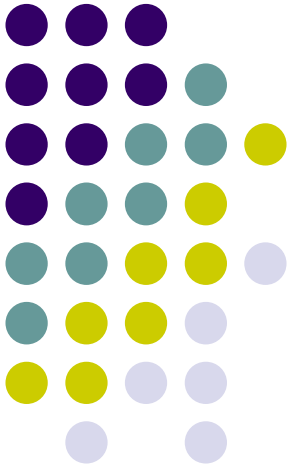
Outline



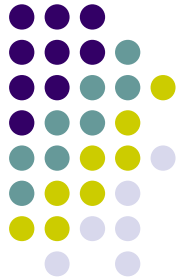
- Basic concepts of accounting ontology – the Resource-Event-Agent (REA) ontology
- Basic concepts of conceptual modeling
- Applying accounting ontology in conceptual modeling
  - User comprehension of REA-patterned conceptual schemas

Basic concepts of accounting ontology

The Resource-Event-Agent (REA) ontology

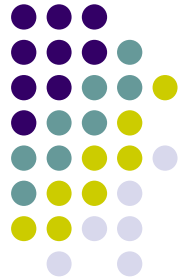


Ontology - definitions



- Philosophy
  - Study of what exists and how it can be conceptualized
- Computer science
  - Specification of a conceptualization
    - Explicit knowledge
    - Formal
    - Shared conceptualization

Enterprise ontology

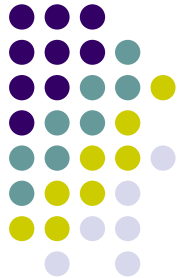


- Specification of business concepts, concept classifications, concept relations and axioms
- Domain ontology where the domain can broadly be defined as ‘business’
  - “The activity of providing goods and services involving financial, commercial and industrials aspects” (Wordnet)
- Scope can be one enterprise (trading partner view) or a collection of enterprises engaged in business relations (independent view)

Example enterprise ontologies

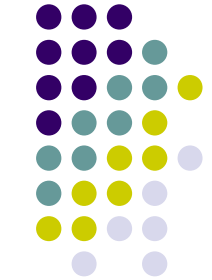
- Resource-Event-Agent (McCarthy)
- E3-value (Gordijn)
- eBMO (Osterwalder)
- Reference ontology (Johannesson)
- UFO (Guizzardi & Wagner)
- …

REA ontology



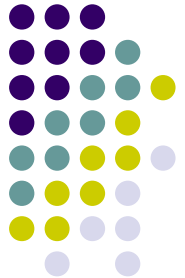
- Evolved from a semantic data model for accounting information
  - Influenced by Chen's ER model
  - Based on accounting theories: events accounting, database accounting
  - Based on micro-economic theories: value cycle/chain theories
  - But also based on empirical observations
    - Notion of patterns as recurrent real-world structures
      - E.g. same structures are involved in buying and selling

REA is an accounting ontology



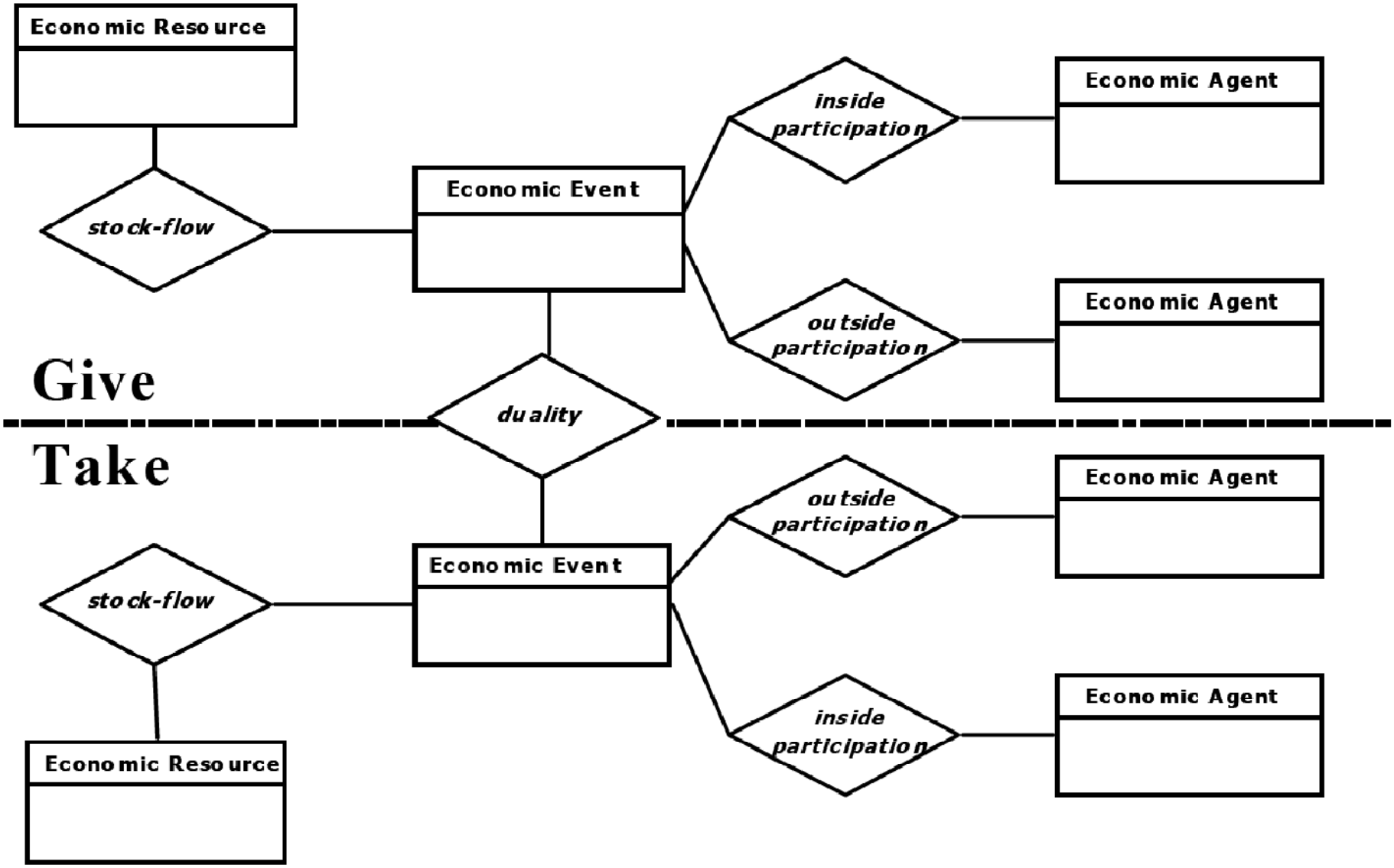
- REA's conceptualization – filter on business reality
  - What changes the value of an enterprise?
    - Recording these value-affecting events and the value composition of the enterprise is what we call 'accounting'
  - Who can be held accountable for this?
    - Accounting enables control of the organization and its members
- REA can also be classified as a task ontology
  - Specification of a conceptualization of a generic task or activity
    - E.g. REA accounting as an ontology application

REA is structure-oriented

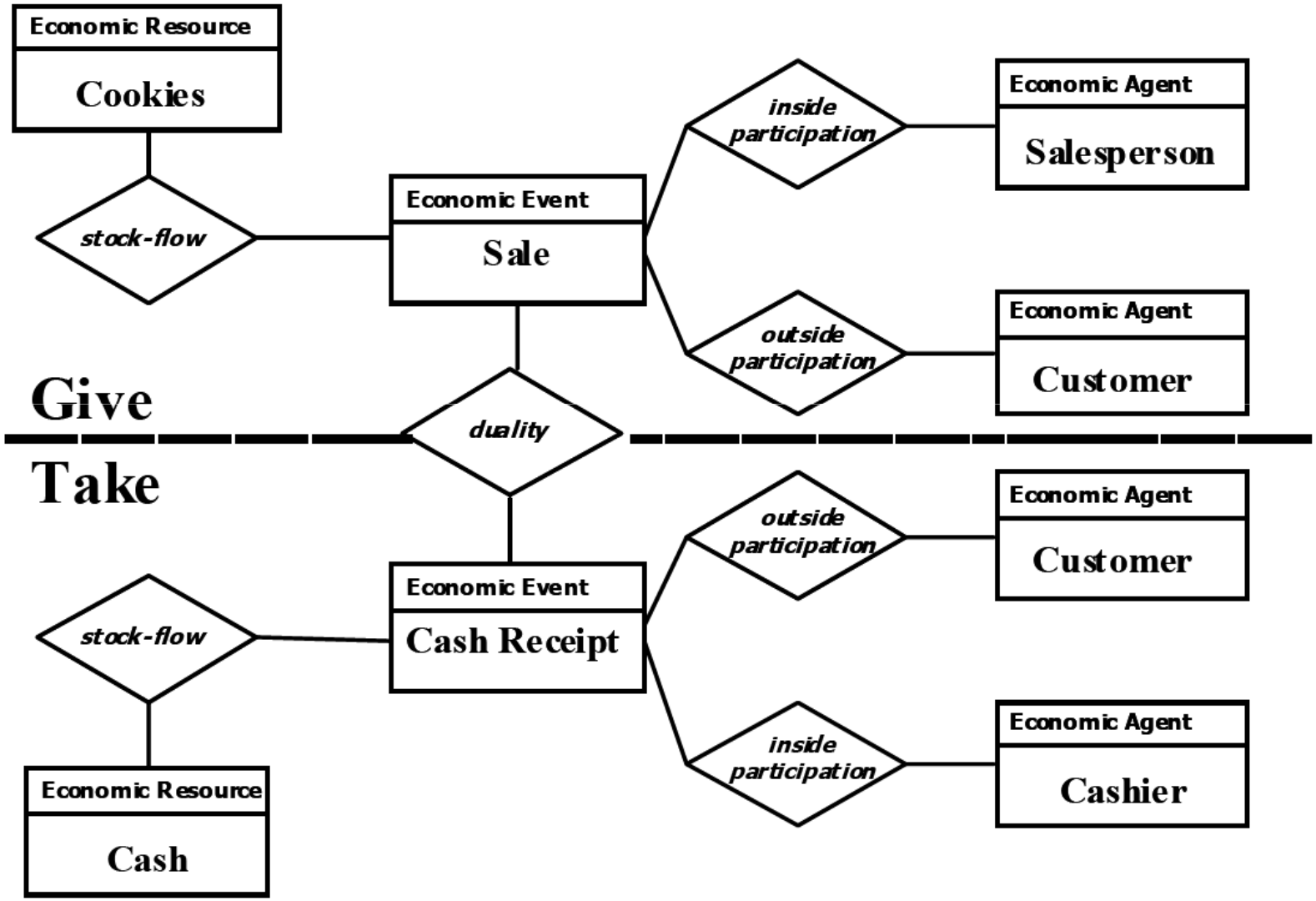


- Real world is described in terms of patterns of relationships between
  - resources (having value),
  - events (affecting this value)
  - agents (having custody over the resources and being responsible for the events)
- Other patterns capture concepts
  - that predict future value changes (e.g. contracts, terms and commitments)
  - or that specify policies for value creation, transfer and consumption (e.g. business rules)

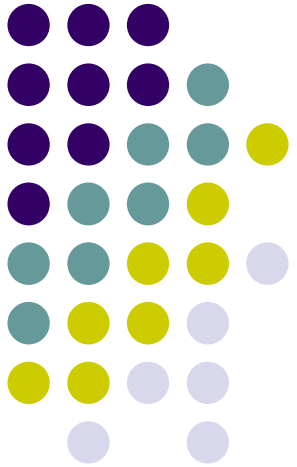
The REA Pattern



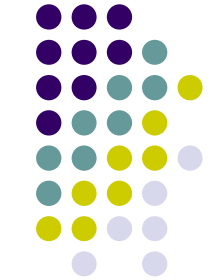
REA Revenue Cycle Example



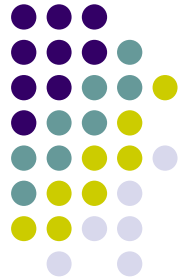
Basic concepts of conceptual modeling



What is a conceptual schema?



- Defines the knowledge about the Universe of Discourse (UoD) of an information system and the functions it needs to perform
  - Memory function
    - Internal representation of the state of the UoD
  - Informative function
    - Provide information on the state of the UoD
  - Active function
    - Actions that modify the state of the UoD
- Specification of the functional requirements of the information system

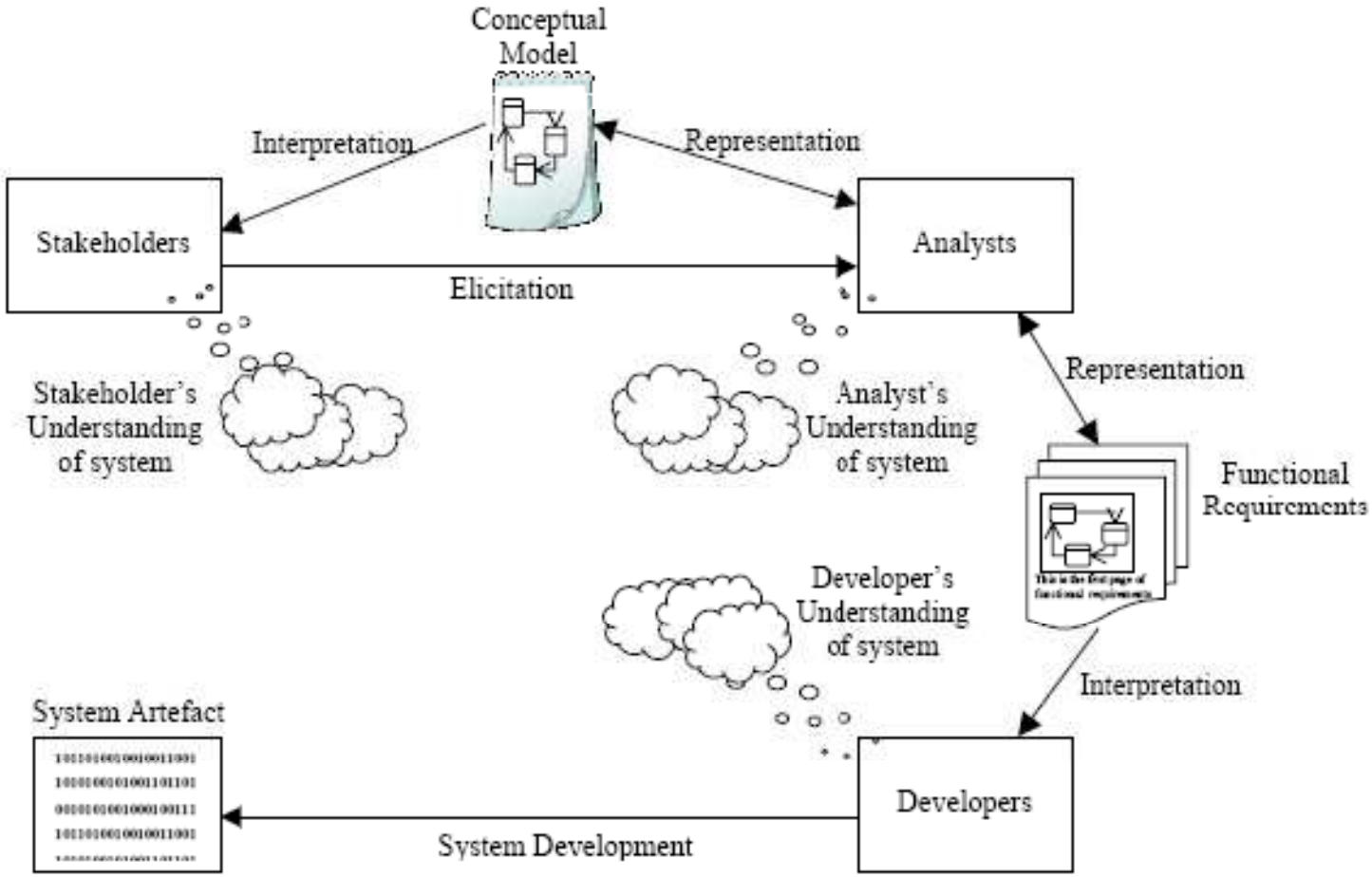


- Types of knowledge described in the conceptual schema
  - Particular state of the UoD that must be represented
  - The potential changes of this state
  - The conditions that must hold for a consistent representation of the state
  - Derivation rules to provide information about the state

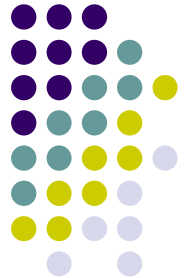
What is conceptual modeling?

- Activity that elicits the conceptual schema of an information system
- Essential part of information systems development
- Undertaken during requirements engineering stage of information systems development, which precedes systems design
  - During requirements elicitation a conceptual schema of the existing and/or desired domain is created
  - During requirements specification a conceptual schema is created that specifies all the functions that the system must perform

Conceptual modeling process

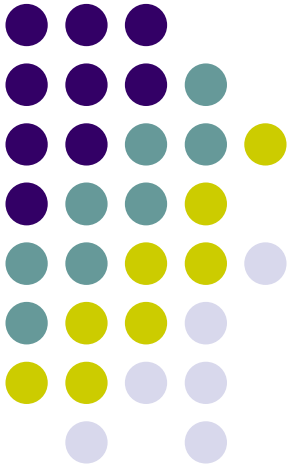


Purposes of conceptual modeling

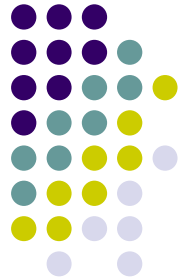


- Supporting communication between users and developers
- Helping analysts understand a domain
- Providing input for the design process
- Documenting the original requirements for future reference

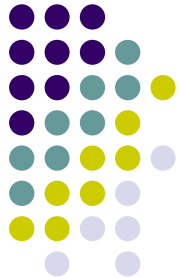
Applying accounting ontology in conceptual modeling



Motivation

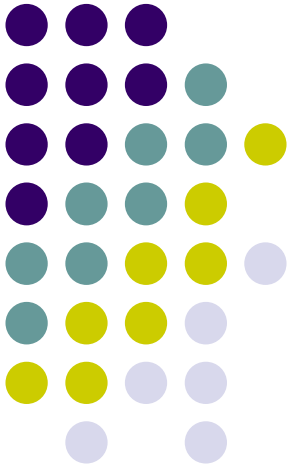


- Accounting ontology
  - Knowledge about accounting
  - Task ontology
- Conceptual schema of an enterprise system
  - Knowledge about
    - one enterprise (intra-enterprise system, e.g. ERP system)
    - or collection of enterprises/households (inter-enterprise systems, e.g. supply chains or value systems)
    - + system functional requirements
  - Application ontology

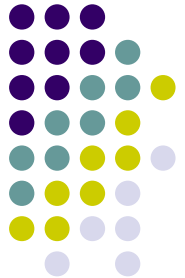


- Guarino's Aufbau-principle
  - Application ontology should be a specialisation of one or more task and/or domain ontologies
  - Reuse of knowledge
- Increase reusability in conceptual modeling & provide guidance for modelers
  - Conceptual schema based on domain/task ontologies
    - Productivity effect / efficiency
    - Quality effect / effectiveness
- Ontology-aware/driven conceptual modeling

User comprehension of REA-based conceptual schemas

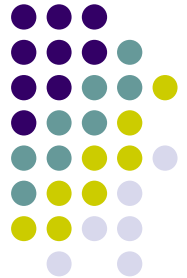


Motivation

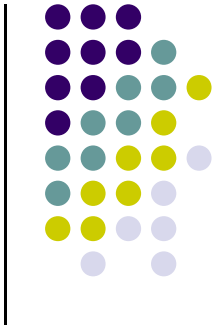


- REA may provide useful approach to teaching accounting information systems
  - Premise
    - Conceptual modeling of business processes/cycles/chains is a key component of AIS
    - Ability to understand conceptual schemas may even be more important than the ability to create them
  - Why useful?
    - REA's structuring-orientation make it a prescriptive approach rather than a 'neutral', descriptive approach like ER modeling, UML, BPMN, …

Context and assumptions of the research

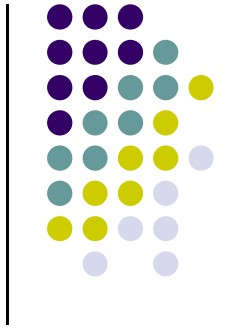


- REA-based conceptual schema
  - Type
    - Structural schema + some integrity constraints
  - Scope
    - Business cycle (e.g. sales-collection, acquisition- payment, payroll, production, finance, …)
  - Perspective
    - Accountability and control
  - Purpose
    - Supporting communication and understanding
    - Conceptual basis for designing an accounting database system



- User
  - Business user
    - Systems development context: future system end-user, ‘pilot’ user, functional domain expert, …
    - Outside systems development context: auditor, business analyst, business process owner/worker, …
  - Not the creator of the schema
- Task
  - Understanding what is modeled
  - Search for information, interpret it, use it, …

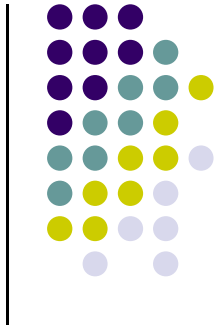
Research question



- *Is the conceptual schema better understood if it is constructed by instantiating the REA pattern?*

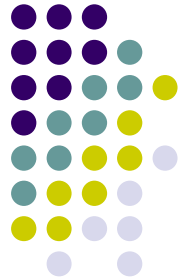
  - Notes
    - If such a schema is represented in a diagrammatic format (ER, UML class diagram, ORM, ...) we call it an REA diagram.
    - A non-REA diagram is an ER, UML class, ORM, ... diagram that does not show an REA pattern instance, but is of the same type and has the same scope, perspective and purpose as an REA diagram.

Proposition



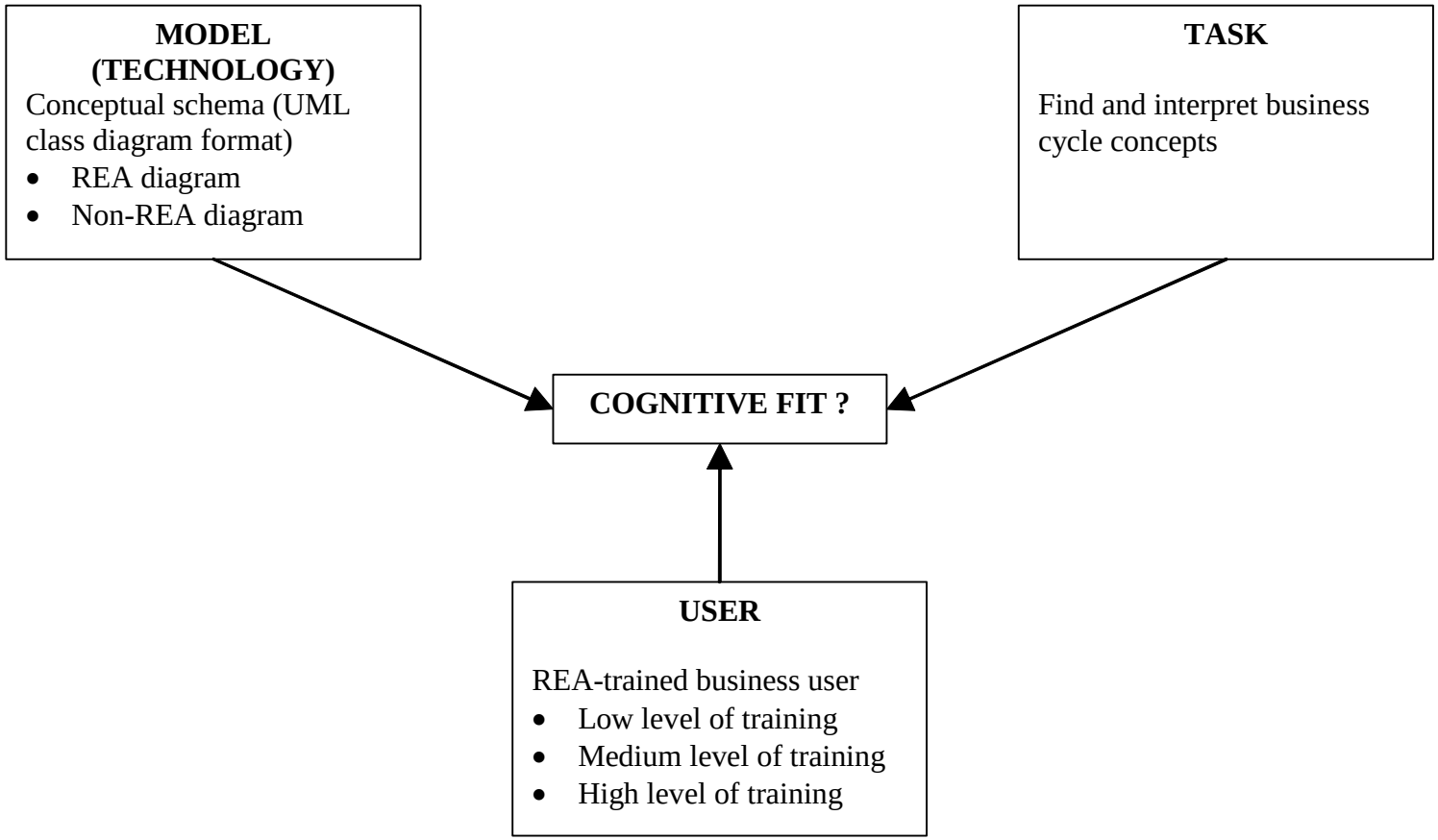
- Given two informationally equivalent conceptual schemas, one REA diagram and one non-REA diagram, then pattern recognition with the REA diagram results in computational efficiency differences
  - Pattern recognition triggers an attention management mechanism → easier to find domain concepts
  - Pattern recognition triggers inference rules → more correct interpretation of domain semantics

Lessons learned from pilot studies

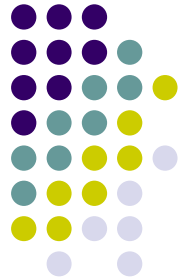


- Expected effect size small to medium (max. 20%)
  - Relatively big sample size needed to obtain statistically significant results (> 100 subjects)
- Difficult operationalization of treatments
  - Surface semantics and diagram layout need to be controlled
- Prior knowledge of REA is a study variable
  - Pattern knowledge needs to be controlled/measured
- Interpretation of observed effects crucial for significance of the contribution and generalizability
  - Psychological model explaining pattern recognition needed

Theoretical framework

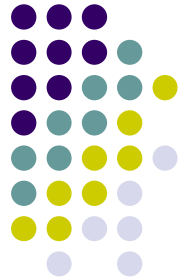


Research questions within Cognitive Fit Theory



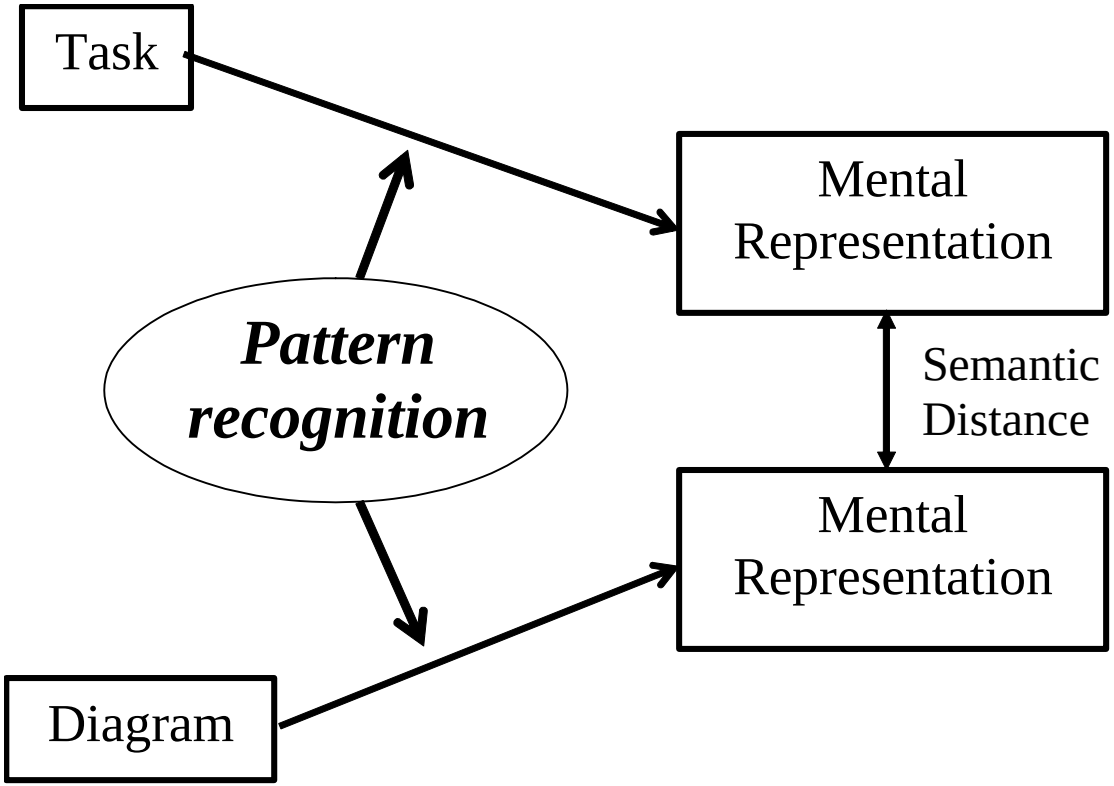
- *For users that are required to understand a conceptual schema, does a diagram with REA pattern occurrences result in a better cognitive fit than a diagram without REA pattern occurrences?*
- *How does prior knowledge of the REA patterns affect cognitive fit?*

Explaining recognition of modeling patterns

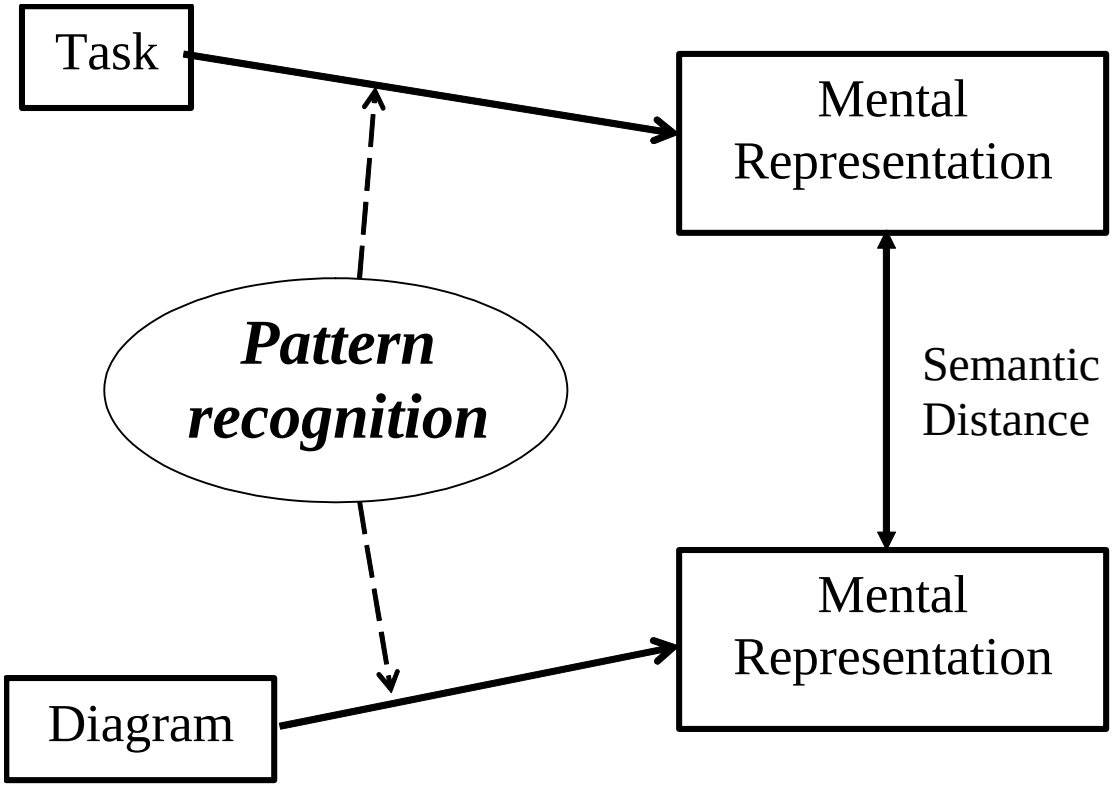


- Template matching theories
  - E.g. Gentner's Structure Mapping Theory
    - Mechanisms that trigger pattern recognition
      - Literal similarity
      - Abstraction
      - Analogy
    - Enabling factors in case of the REA transaction pattern
      - Localization
      - Secondary notation
- Schema or production system theories
  - E.g. Anderson's Adaptive Control of Thought (ACT) framework
    - Assume internalized knowledge structure (learning)

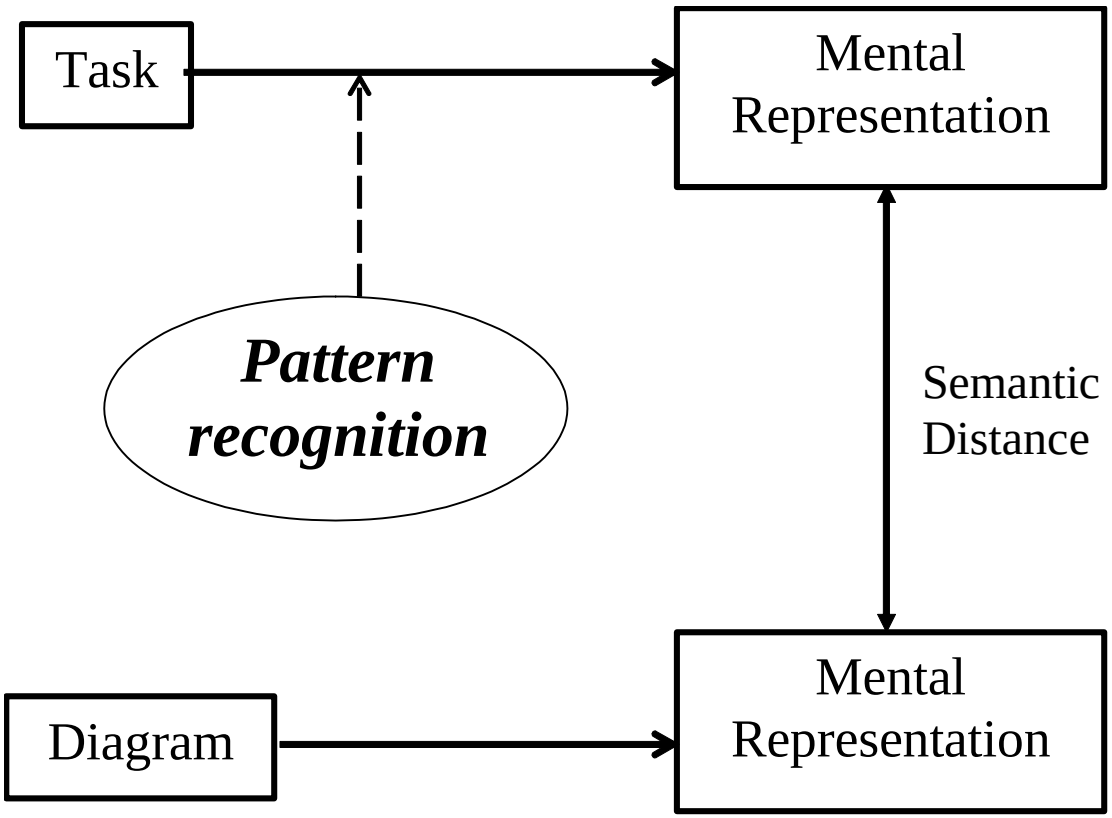
REA pattern presence in LTM: high
REA pattern presence in diagram: yes



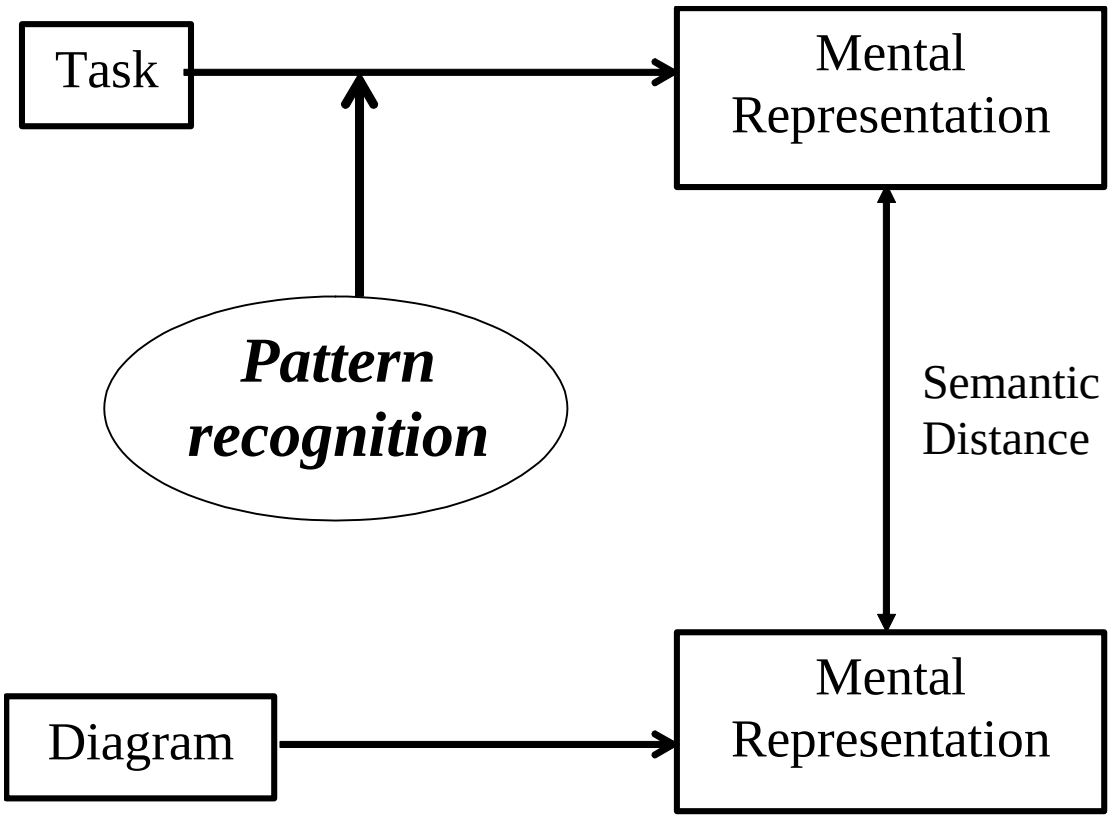
REA pattern presence in LTM: low
REA pattern presence in diagram: yes



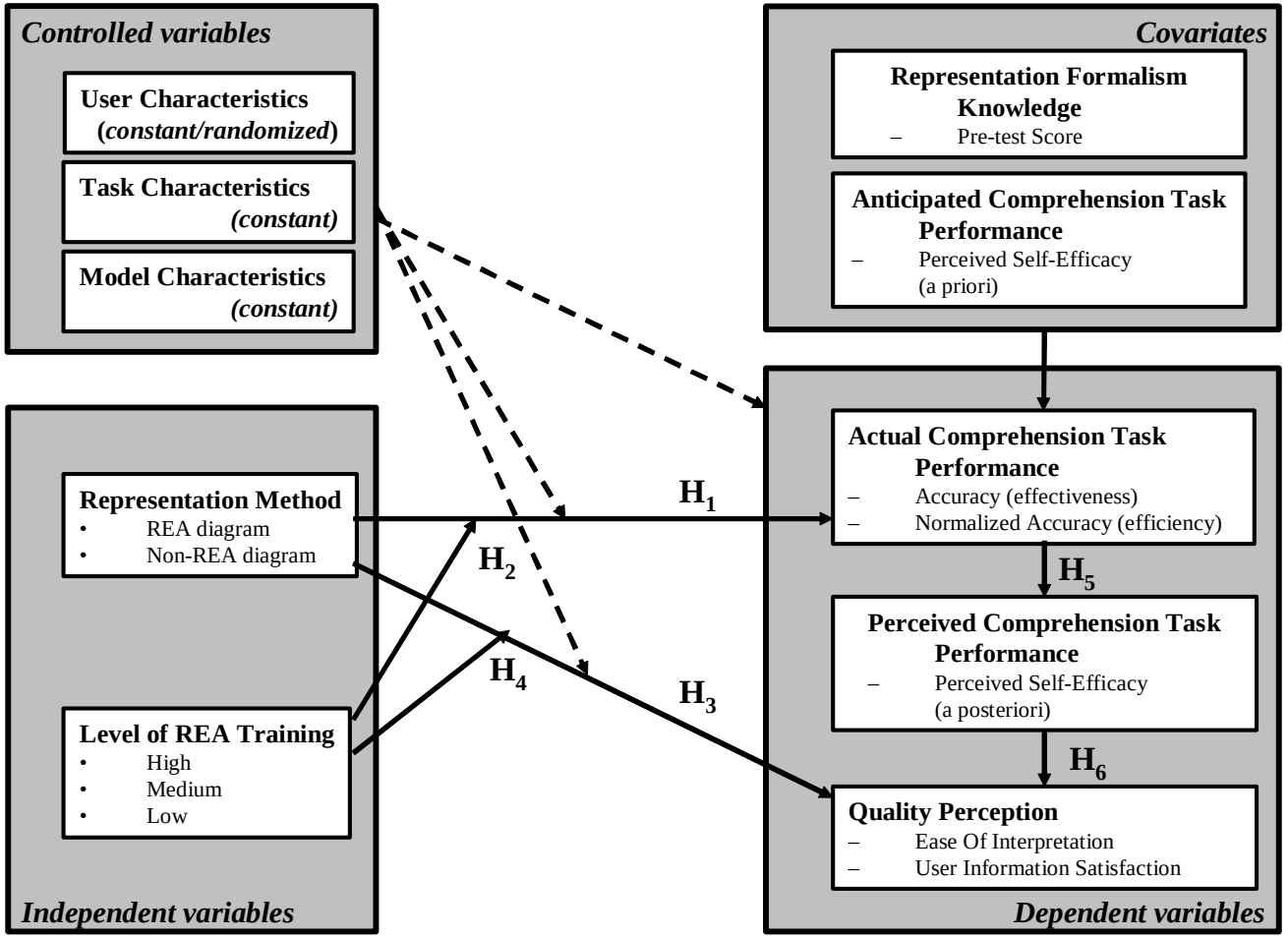
REA pattern presence in LTM: low
REA pattern presence in diagram: no



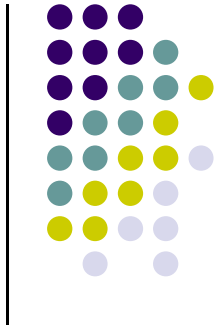
REA pattern presence in LTM: high
REA pattern presence in diagram: no



Research model

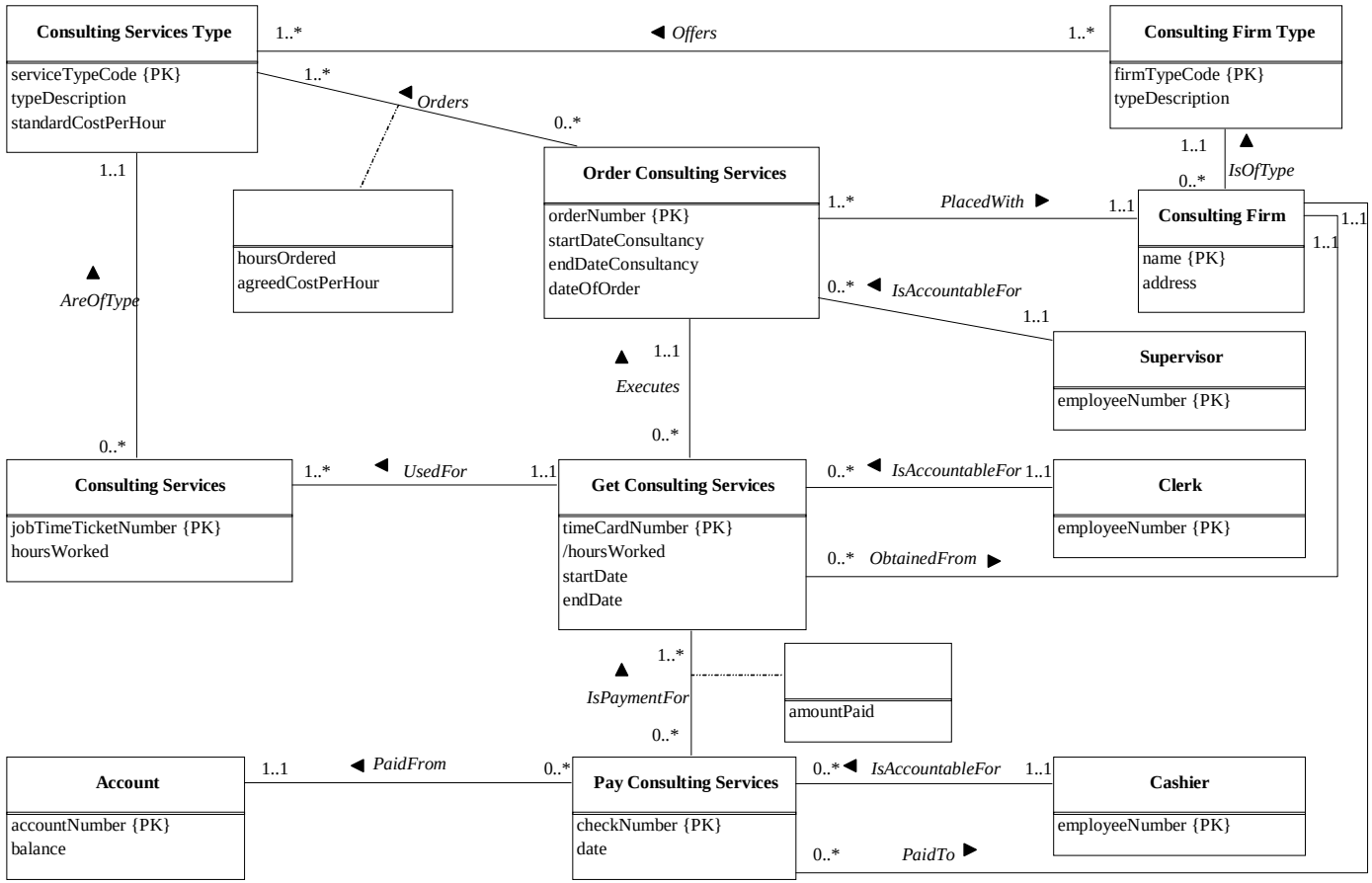


Design

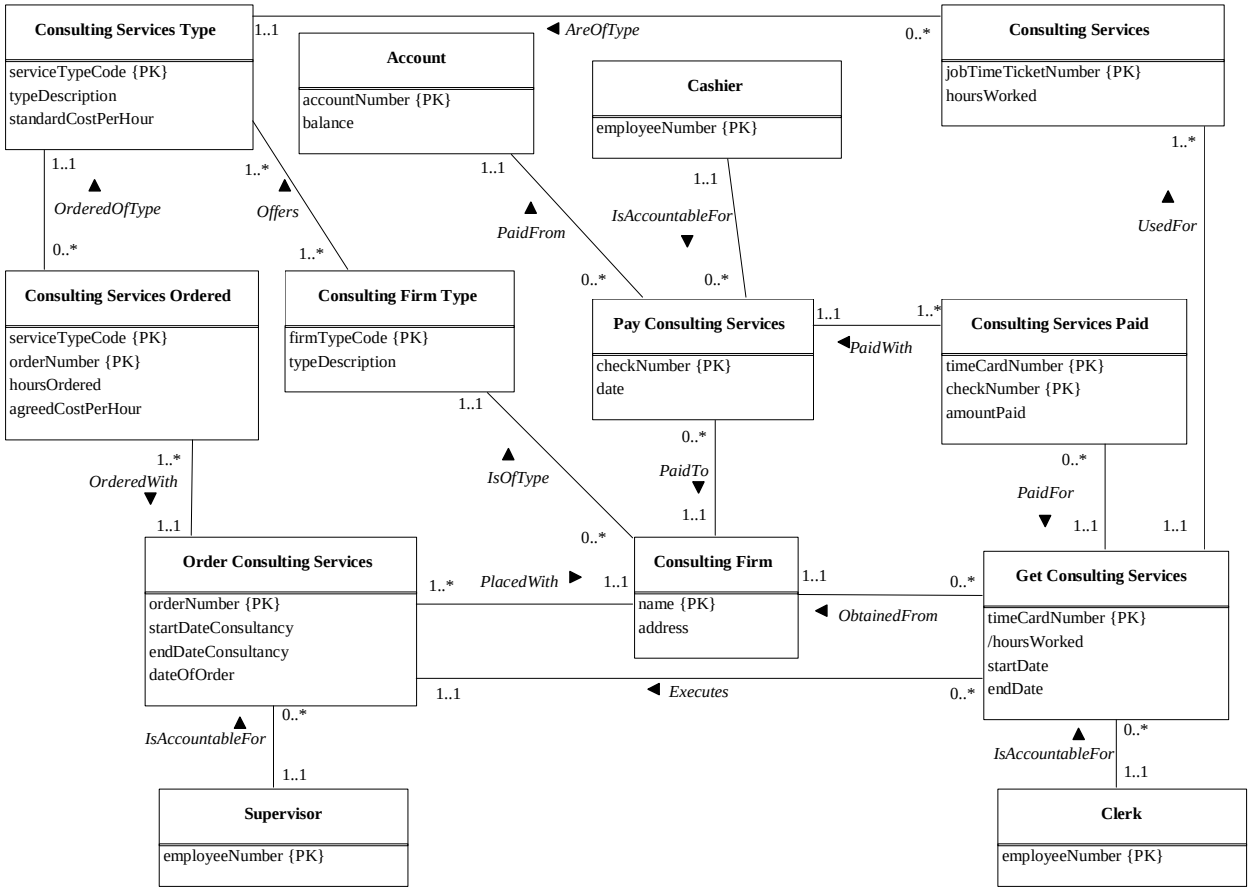


- 126 business students
- Between-subject, 2 x 3 factorial design
- Factor 1: representation method (random allocation)
  - Non-REA diagram (62) derived from REA diagram (62) by means of information-preserving transformations
    - Objectification of relationships
    - Visual restructuring of diagram elements
- Factor 2: level of REA training (measured variable)
  - Low level: 1 hour of class on REA reference models (22)
  - Medium level: low level training + practical exercises (69)
  - High level: medium level training + additional practical exercises (33)

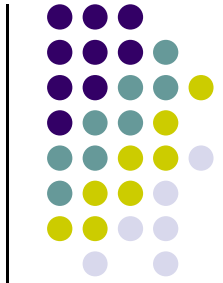
REA diagram


Consulting Services Type
serviceTypeCode {PK}
typeDescription
standardCostPerHour
Offers
Consulting Firm Type
firmTypeCode {PK}
typeDescription
Orders
hoursOrdered
agreedCostPerHour
Order Consulting Services
orderNumber {PK}
startDateConsultancy
endDateConsultancy
dateOfOrder
PlacedWith
Consulting Firm
name {PK}
address
IsOfType
AreOfType
IsAccountableFor
Supervisor
employeeNumber {PK}
Executes
Consulting Services
jobTimeTicketNumber {PK}
hoursWorked
UsedFor
Get Consulting Services
timeCardNumber {PK}
/hoursWorked
startDate
endDate
IsAccountableFor
Clerk
employeeNumber {PK}
ObtainedFrom
IsPaymentFor
amountPaid
Account
accountNumber {PK}
balance
PaidFrom
Pay Consulting Services
checkNumber {PK}
date
IsAccountableFor
Cashier
employeeNumber {PK}
PaidTo

Non-REA diagram



Task, measures and motivation



- Inspired by previous research
  - Representation Formalism Knowledge Pre-test: Parsons and Cole (2005)
  - Comprehension questions: Bodart et al. (2001), Burton-Jones and Weber (2003), Gemino and Wand (2005)
  - Perceived ease of interpretation measure: Gemino and Wand (2005)
  - User information satisfaction measure: Dunn and Grabski (2001)
  - Perceived self-efficacy measure: Ryan et al. (2000), Smith et al. (2003)
- Motivation
  - Feedback
  - Prizes (i-Pods)

Results

Tests of Between-Subjects Effects

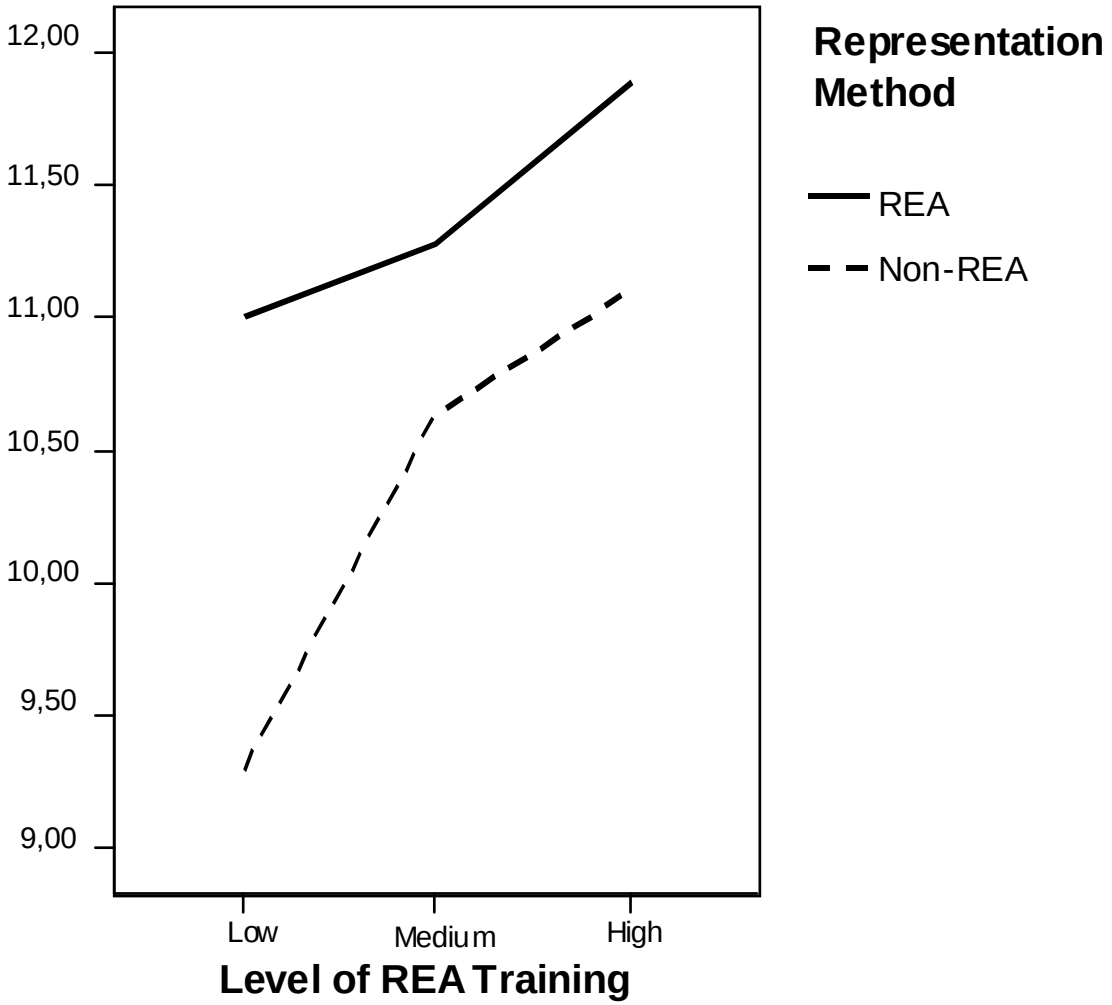
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Accuracy	80,020[a]	7	11,431	3,950	,001	,192
	Normalized Accuracy	,686[b]	7	,098	1,170	,325	,066
Intercept	Accuracy	57,791	1	57,791	19,970	,000	,147
	Normalized Accuracy	,333	1	,333	3,983	,048	,033
Pre-test Score	Accuracy	22,144	1	22,144	7,652	,007	,062
	Normalized Accuracy	,004	1	,004	,045	,833	,000
PSE_before	Accuracy	3,876	1	3,876	1,339	,250	,011
	Normalized Accuracy	,108	1	,108	1,287	,259	,011
Representation Method	Accuracy	27,268	1	27,268	9,422	,003	,075
	Normalized Accuracy	,367	1	,367	4,387	,038	,036
Level of REA Training	Accuracy	23,890	2	11,945	4,128	,019	,066
	Normalized Accuracy	,007	2	,004	,044	,957	,001
Representation Method × Level of REA Training	Accuracy	4,692	2	2,346	,811	,447	,014
	Normalized Accuracy	,367	2	,183	2,192	,116	,036
Error	Accuracy	335,690	116	2,894			
	Normalized Accuracy	9,711	116	,084			
Total	Accuracy	15288,000	124				
	Normalized Accuracy	83,293	124				
Corrected Total	Accuracy	415,710	123				
	Normalized Accuracy	10,397	123				

a. R Squared = ,192 (Adjusted R Squared = ,144)

b. R Squared = ,066 (Adjusted R Squared = ,010)

Table 3. MANCOVA Comprehension Task Performance

Estimated Marginal Means of Accuracy



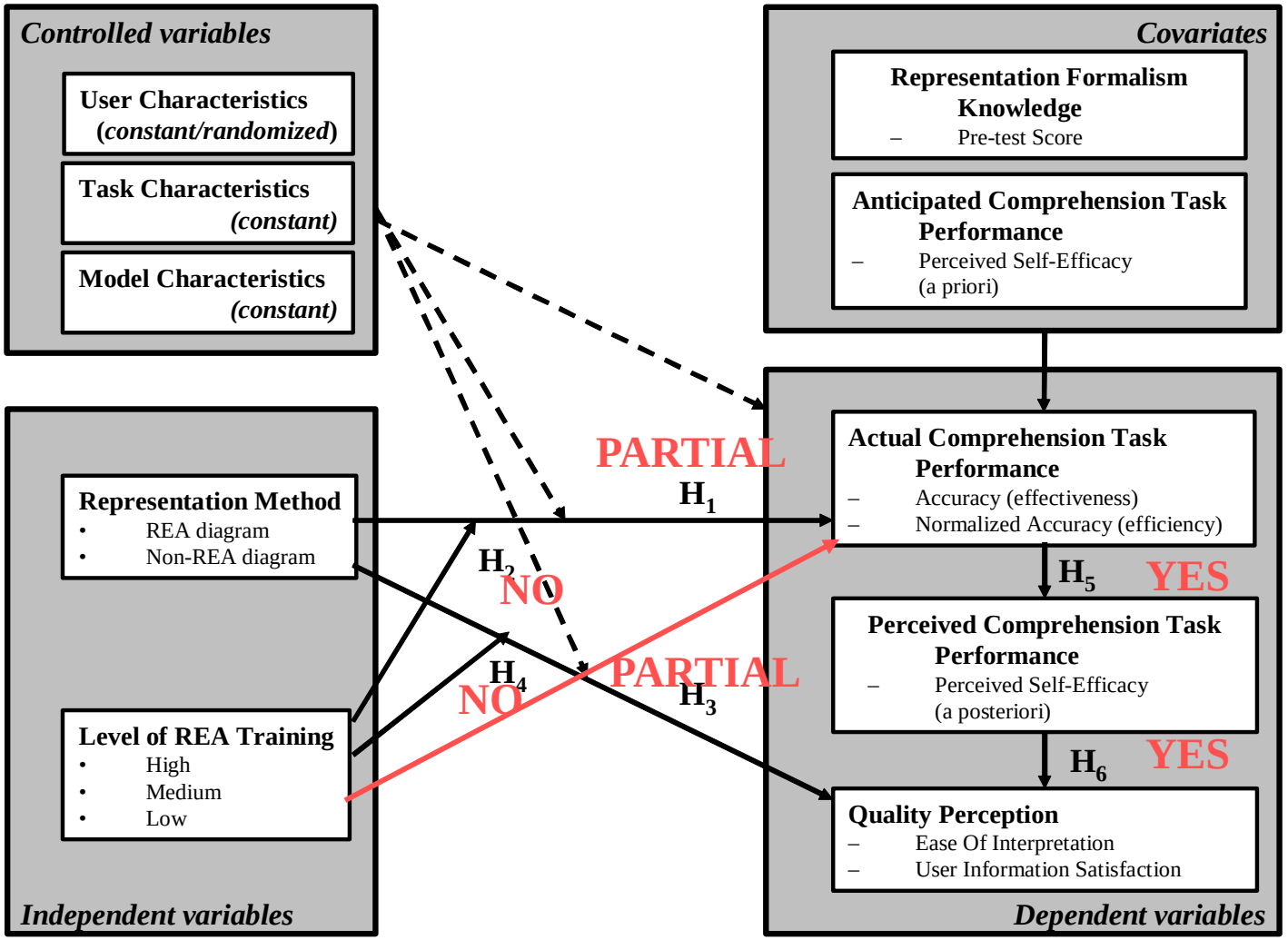
Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	UIS	34,65 [a]	6	5,775	8,023	,000	,291
	PEOI	64,14 [b]	6	10,69	11,80	,000	,377
Intercept	UIS	29,91	1	29,91	41,56	,000	,262
	PEOI	3,479	1	3,479	3,840	,052	,032
PSE_after	UIS	28,12	1	28,12	39,06	,000	,250
	PEOI	51,55	1	51,55	56,90	,000	,327
Representation Method	UIS	,765	1	,765	1,063	,305	,009
	PEOI	2,776	1	2,776	3,064	,083	,026
Level of REA Training	UIS	3,144	2	1,572	2,183	,117	,036
	PEOI	1,971	2	,985	1,088	,340	,018
Represenation Method × Level of REA Training	UIS	,866	2	,433	,601	,550	,010
	PEOI	,450	2	,225	,248	,781	,004
Error	UIS	84,22	117	,720			
	PEOI	105,99	117	,906			
Total	UIS	2629,87	124				
	PEOI	1913,88	124				
Corrected Total	UIS	118,87	123				
	PEOI	170,13	123				

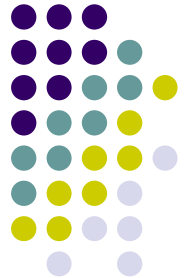
a. R Squared = ,291 (Adjusted R Squared = ,255)

b. R Squared = ,377 (Adjusted R Squared = ,345)

Table 5. MANCOVA Quality Perception


Controlled variables
User Characteristics (constant/randomized)
Task Characteristics (constant)
Model Characteristics (constant)
Covariates
Representation Formalism Knowledge
– Pre-test Score
Anticipated Comprehension Task Performance
– Perceived Self-Efficacy (a priori)
Representation Method
• REA diagram
• Non-REA diagram
Level of REA Training
• High
• Medium
• Low
Independent variables
PARTIAL
H1
H2
NO
H4
NO
PARTIAL
H3
Actual Comprehension Task Performance
– Accuracy (effectiveness)
– Normalized Accuracy (efficiency)
H5
YES
Perceived Comprehension Task Performance
– Perceived Self-Efficacy (a posteriori)
H6
YES
Quality Perception
– Ease Of Interpretation
– User Information Satisfaction
Dependent variables

Conclusions with respect to REA's use in AIS education



- Even at low levels of REA training, structuring ER diagrams according to REA principles provides understanding benefits
  - Pattern recognition occurs with one hour of training
- More REA training => more understanding benefits
  - Even when ER diagrams are not REA-structured
- But of course, representation formalism knowledge is also important
  - Also train students in the use of conceptual modeling languages such as ER, UML, BPMN, …