Increasing the Semantic Transparency of the KAOS Goal Model Concrete Syntax

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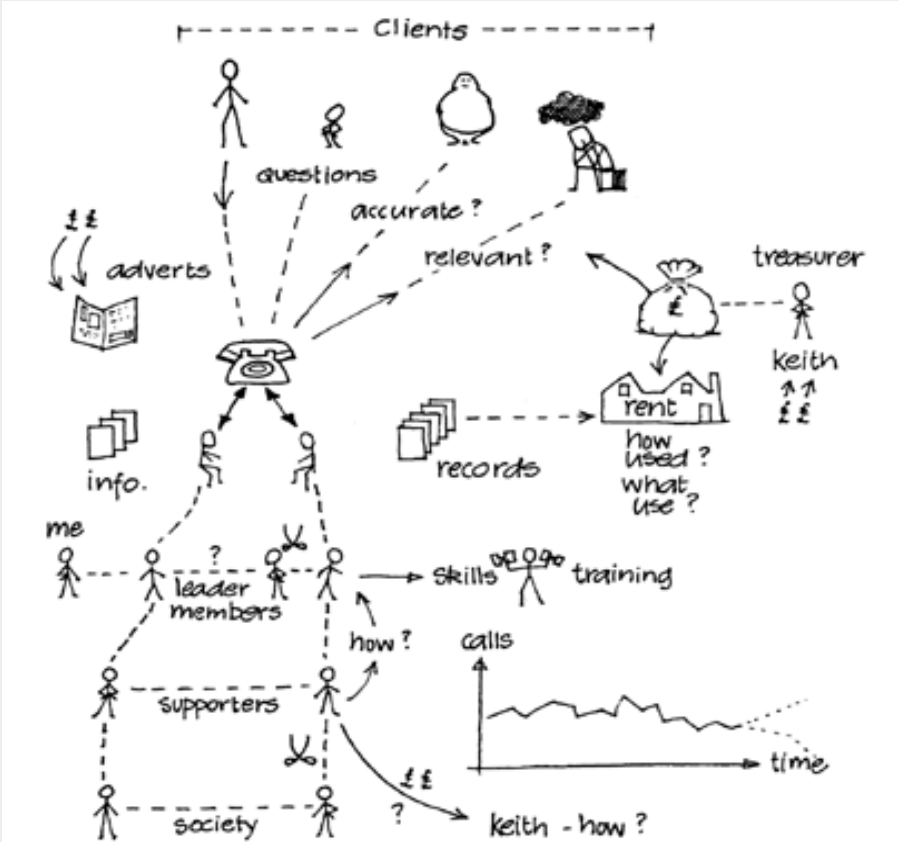
RE SUCCESS DEPENDS ON THE QUALITY OF THE COMMUNICATION AMONG STAKEHOLDERS

REQUIREMENTS VISUAL NOTATIONS ARE PERCEIVED AS EFFECTIVE FOR COMMUNICATION



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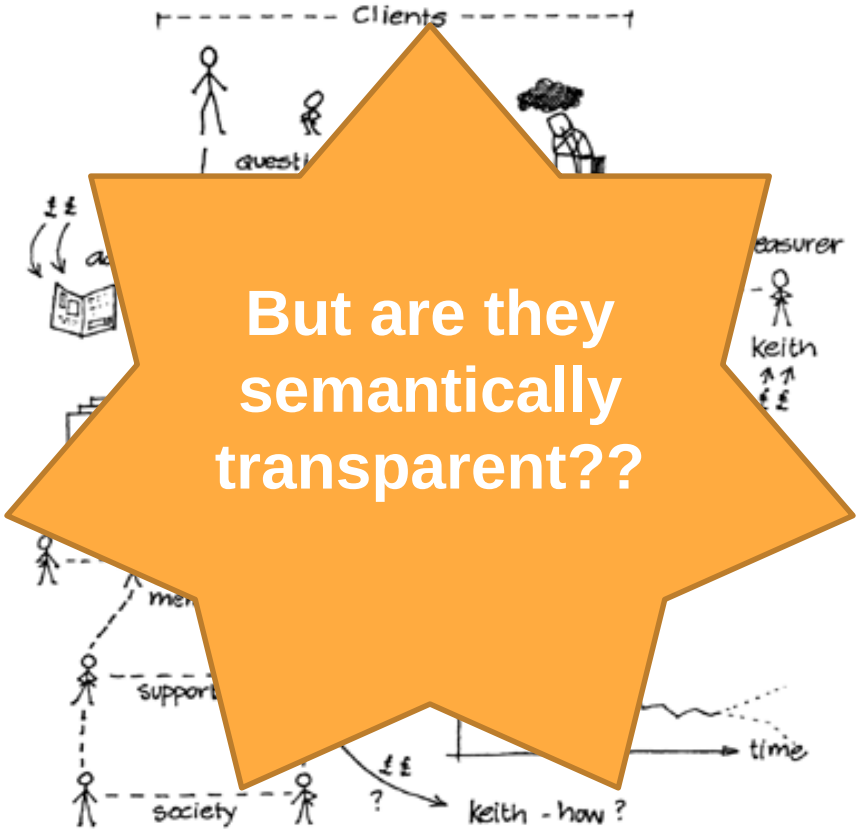
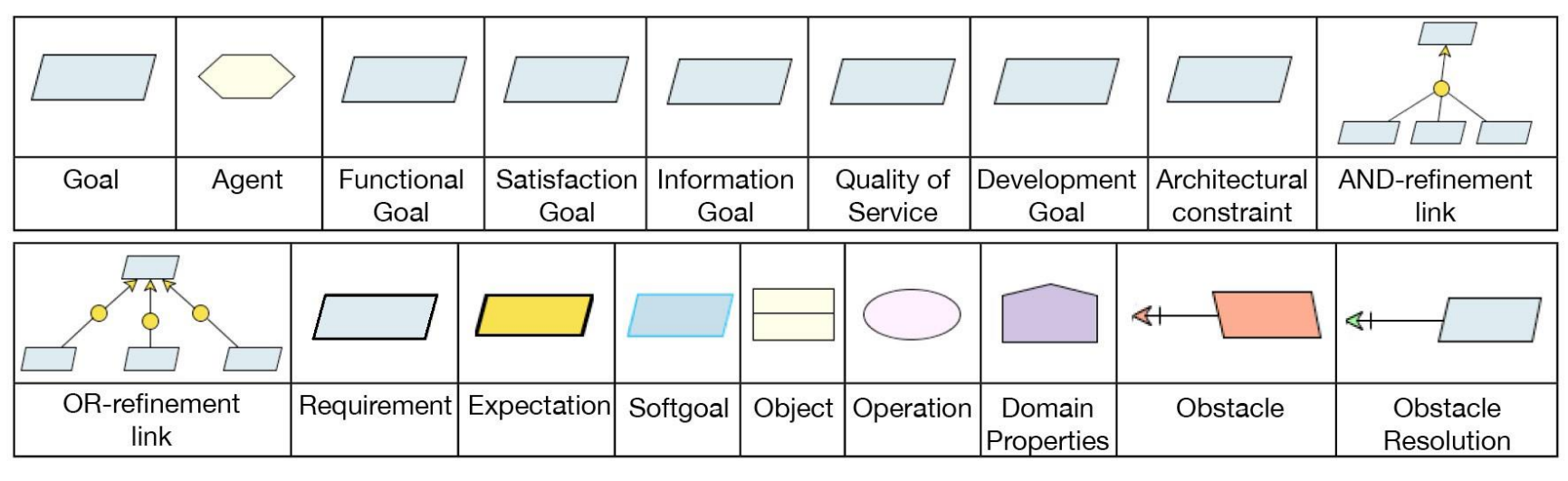


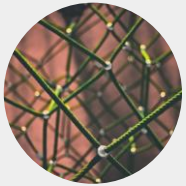
The KAOS approach and notation

Is Standard *KAOS* Semantically opaque?



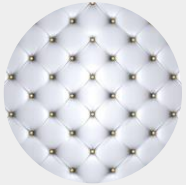
Goals are a prescriptive intention statement about a system whose satisfaction, in general, needs cooperation of agents that configure the system.

PHYSICS OF NOTATIONS: FOR BETTER HUMAN COMMUNICATION AND PROBLEM SOLVING

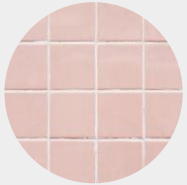


cognitive integration

semiotic clarity



cognitive fit



graphic economy

perceptual discriminability

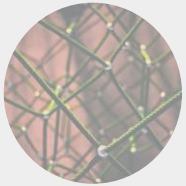
dual coding

manageable complexity

visual expressiveness

semantic transparency

THE EXTENT TO WHICH THE MEANING OF A SYMBOL CAN BE INFERRED FROM ITS APPEARANCE



cognitive integration

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RESEARCH QUESTIONS

1. RQ1. Is the KAOS visual notation semantically opaque?

2. RQ2. Can participants with no knowledge in modelling languages design more semantically transparent symbols than participants with knowledge in modelling languages?

3. RQ3. Which visual notation (standard, stereotype, or prototype) is more semantically transparent?

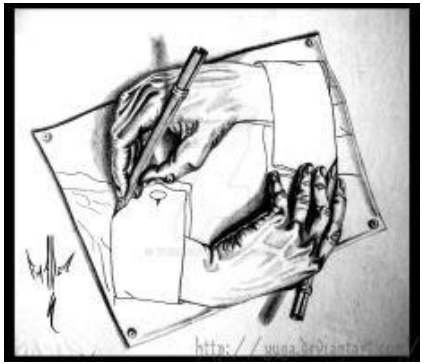
Research design

- **Symbolisation experiment**
  - 99 novice participants designed symbols for KAOS concepts, a task normally reserved for experts
- **Stereotyping analysis**
  - we identified and organised categories with the most common symbols produced for each KAOS concept. This defined the stereotype symbol set.
- **Prototyping experiment**
  - 88 novice-participants chose the symbols they consider to better represent each KAOS concept. The most voted symbols for each KAOS concept defined the prototype symbol set
- **Semantic transparency experiment**
  - we evaluated the ability of 52 participants to infer the meanings of novice-designed symbols (stereotype and prototype symbol set) compared stand. KAOS

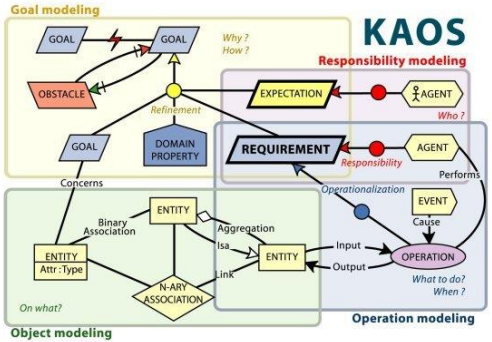
Study 1 : Symbolisation experiment

- The goal of this study was to obtain **candidate symbols** drawn by novices to illustrate **18 KAOS goal models concepts**

99 participants:
53 with no knowledge,
46 with knowledge



For each concept, participants were asked to create a visual representation



Provided a requirements description, we asked participants to represent it using the visual symbols they proposed

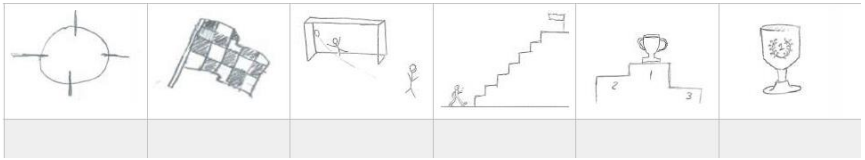
Study 1 : Symbolisation experiment - Results

- The participants produced a total of 1518 symbols,
  - 723 of which by the WNKML and 795 by the WKML group (response rate of 85.2%)
  - The participants from the WKML group had a higher response rate than participants from the WNKML group
- The overall results suggest that both groups encountered more difficulties when creating the KAOS model than when proposing symbols for each concept
- The WNKML group had more difficulty than the WKML, in both parts of the questionnaire

Study 2 : Stereotyping analysis

- This study identified the most common symbols produced by the participants, the stereotype symbol set, for each KAOS concept in Study 1
- We categorised the symbols based on their visual and conceptual similarity
- We then combined the categories of symbols produced by both groups and counted the number of members in each category.
- We then selected the most representative category for each concept, resulting in the stereotype symbol set.

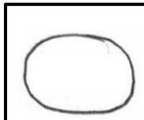
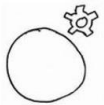
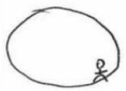
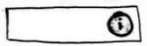
Goal

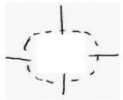
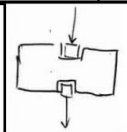
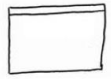
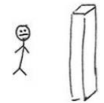


Agent

Study 2 : Stereotyping analysis - Results

- The degree of stereotypy, or stereotype weight, measures the level of consensus about a concept visual representation.
- The average degree of stereotypy of the stereotype symbols was .212%, confirming the difficulty in representing such abstract concepts
- Both groups contributed similarly to the stereotype symbol set

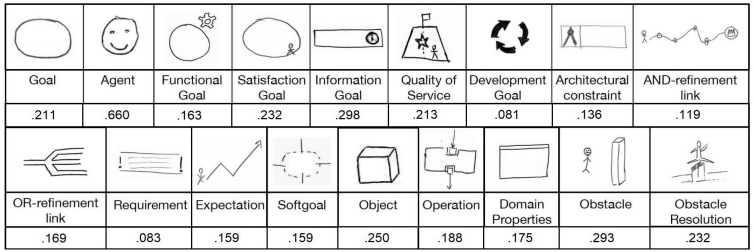
								
Goal	Agent	Functional Goal	Satisfaction Goal	Information Goal	Quality of Service	Development Goal	Architectural constraint	AND-refinement link
.211	.660	.163	.232	.298	.213	.081	.136	.119

								
OR-refinement link	Requirement	Expectation	Softgoal	Object	Operation	Domain Properties	Obstacle	Obstacle Resolution
.169	.083	.159	.159	.250	.188	.175	.293	.232

Study 3 : Prototyping experiment

- Novice-participants analysed symbols produced in Study 1 and categorized in Study 2 and were asked to choose which best represented each KAOS concept

80 participants:
None from Study 1.
WNKML - 56
WKML - 24



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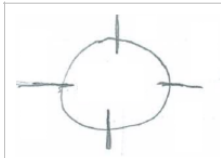
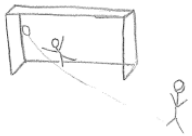
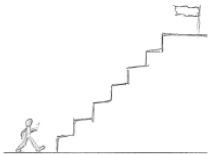
.169	.083	.159	.159	.250	.188	.175	.293	.232

Participants were asked to choose the symbol that represents the best visual metaphor for each concept.

Study 3 : Prototyping experiment

Goal is a prescriptive statement of intent about some system (existing or to be) whose satisfaction in general requires the cooperation of some of the agents forming that system (in this context, the word "system" refers to both to the software under consideration and its environment).



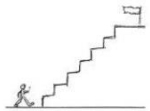
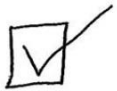
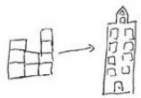
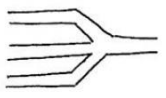
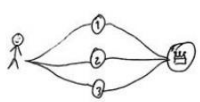
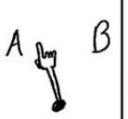
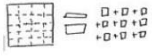
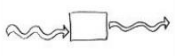




Agent is an active component, such as a human, a device, legacy software, or software-to-be component that plays some role towards goal satisfaction. Some agents define the software, whereas others define the environment.



Study 3 : Prototyping experiment - Results

- The most frequently chosen symbol for each concept was included in the prototype symbol set
- The overall level of consensus among judgement was lower than .5 for most symbols.
- On average, participants from the WKML group selected less voted elements than those from the WNKML

								
Goal	Agent	Functional Goal	Satisfaction Goal	Information Goal	Quality of Service	Development Goal	Architectural constraint	AND-refinement link
.450	.663	.413	.300	.325	.788	.538	.425	.375
								
OR-refinement link	Requirement	Expectation	Softgoal	Object	Operation	Domain Properties	Obstacle	Obstacle Resolution
.363	.663	.388	.263	.463	.538	.363	.263	.313

Study 4 : Semantic transparency experiment

- To evaluate the semantic transparency of standard, stereotype and prototype symbol sets
- We conducted a blind interpretation study where participants inferred the concept (content) associated with each symbol (form).
- Novice-participants analysed symbols produced in Study 1 and choose which best represents each KAOS concept.

52 participants:
None from Studies 1 & 3
WNKML - 17
WKML - 35

Study 4 : Semantic Transparency experiment

Agent is an active component, such as a human, a device, legacy software, or software-to-be component that plays some role towards goal satisfaction. Some agents define the software, whereas others define the environment.

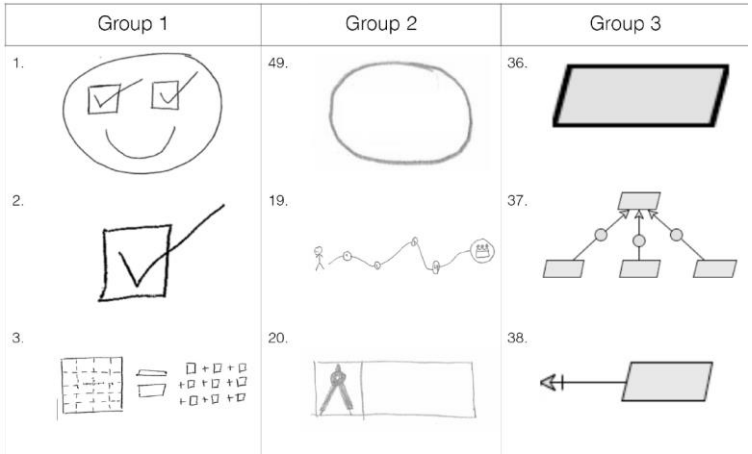
AND-refinement link relates a goal to a set of subgoals (called refinement) possibly conjoined with domain properties; this means that satisfying all subgoals in the refinement is a sufficient condition in the domain for satisfying the goal.

Architectural constraint is a non-functional goal that refers to domain-specific features of the environment agents and relationships among them to be taken into account during architectural design such as the distribution of human agents, organisation data or physical devices in the environment.

Development goal is a non-functional goal that refers to standard software quality criteria such as maintainability, reusability, etc.

Domain Properties are descriptive statements about the environment e.g., physical laws, organisational norms, etc.

Concept	Corresponding figure(s)		
	Group 1	Group 2	Group 3
Agent			
AND-refinement link			
Architectural constraint			
Development Goal			
Domain Properties			
Expectation			
Functional Goal			
Goal			



We provide a table containing the 3 symbol sets. Participants are asked to fill a Matching Table, by matching the symbols from each of the 3 symbol sets with each of the 18 KAOS concepts

Study 4 : Hypotheses, parameters and variables.

- The independent variable is the symbol set (i.e., standard, stereotype or prototype). The dependent variables are
  - ***Semantic transparency coefficient***: the degree of proximity between a symbol and the semantic construct represented by it.

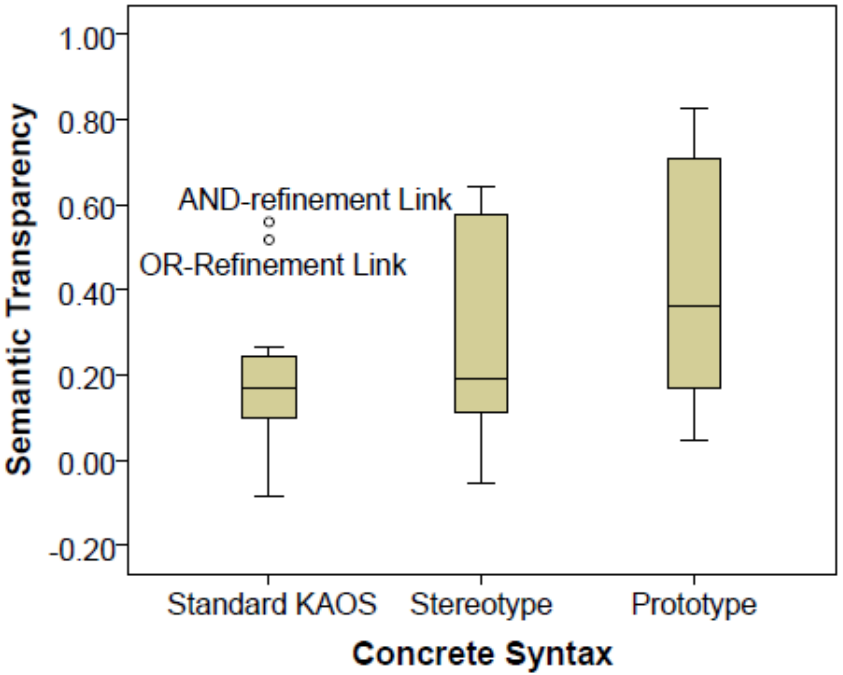
$$\frac{\text{maximum frequency- expected frequency}}{\text{total responses - expected frequency}}$$

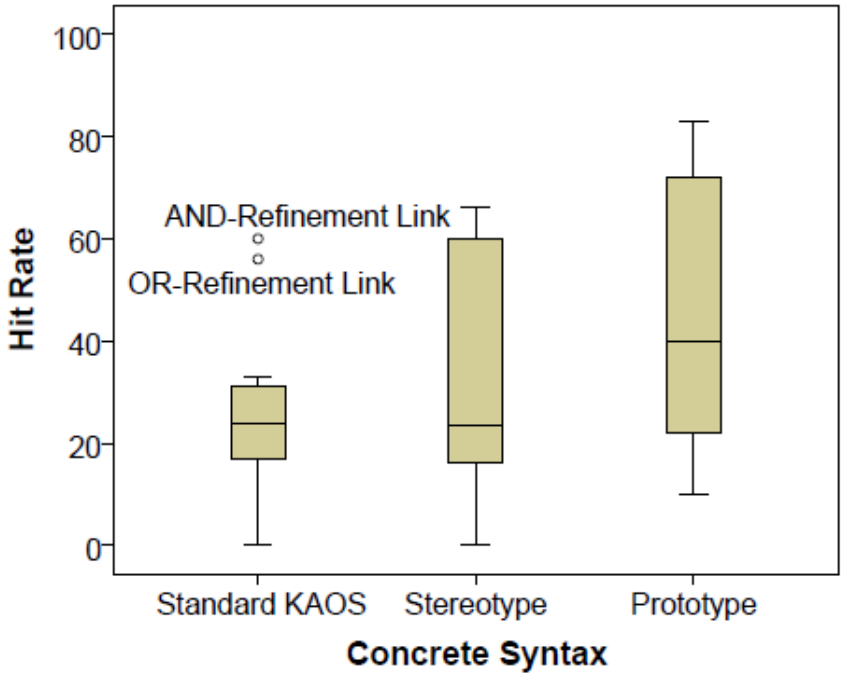
  - ***Hit rate***, an indicator for measuring correct symbols comprehension
- Hypotheses for Semantic Transparency and Hit Rate

Hypotheses	Description
H_{1ST}	Stereotype is more semantically transparent than standard
H_{2ST}	Prototype is more semantically transparent than standard
H_{3ST}	Prototype is more semantically transparent than stereotype
H_{4HR}	Stereotype has a higher hit rate than standard
H_{5HR}	Prototype has a higher hit rate than standard
H_{6HR}	Prototype has a higher hit rate than stereotype


Results for the
Semantic
Transparency
coeficient
and Hit Rate

The Prototype symbol set has a higher Semantic Transparency and Hit Rate





Semantic transparency

- Our results suggest that the prototype concrete syntax is more semantically transparent than the standard concrete syntax.
    - We found no statistically significant differences between the prototype and the stereotype concrete syntaxes, or between the stereotype and the standard concrete syntaxes.
- Also, the three concrete syntaxes are semantically transparent, even if in different degrees.
    - The standard KAOS concrete syntax differs significantly from a semantically opaque concrete syntax (which would have a mean semantic transparency score around 0)


Discussion

RQ1. Is the KAOS visual notation semantically opaque?

- The results do not allow us to conclude that the standard KAOS symbol set is semantically opaque
- 67% of the participants of the semantic transparency experiment are from the WKML group. Some of them had contact with the KAOS language as part of a SE course
- This might explain the relatively high semantic transparency coeficient values for the standard KAOS symbol set

RQ2. Can participants with no knowledge in modelling languages design more semantically transparent symbols than participants with knowledge in modelling languages?

- The symbols produced by the WKML group are clearly influenced by the modelling languages they know, namely UML
- The symbols produced by the WNKML group are less formal, more creative
- In the prototyping experiment (Study 3), the symbols drawn by the WNKML group had more votes than the ones drawn by the WKML group.

RQ2. Can participants with no knowledge in modelling languages design more semantically transparent symbols than participants with knowledge in modelling languages?

- In Study 4, the prototype symbol set had significantly better results
  → symbols drawn by the WNKML group produced symbols that represent better visual metaphors for KAOS concepts.
- Some participants had a background in CS, were significantly more able to produce a model with their proposed symbols but were less creative

RQ3 -- Which visual notation (standard, stereotype, or prototype) is more semantically transparent?

- The results show that there is a statistically significant difference between prototype and standard KAOS in terms of semantic transparency coeficient and success rate
- We conclude that the prototype symbol set is more cognitively effective than the standard KAOS in terms of semantic transparency.

Implications to practice

- The semantic transparency is only one of the 9 principles in the PoN. Improving a notation according to one particular principle does not necessarily lead to a more cognitively effective notation, as this change may have detrimental side effects with respect to other principles.
- For example, the ease of drawing the symbols is relevant for cognitive fitness, but is not considered here.
- Although a symbol may be easily recognisable as mnemonic of a particular term, this may be a misrepresentation of a concept denoted by the same name, but with a significantly different semantics.
- Also, the symbols were evaluated in isolation, rather than in the context of requirements models.

THREATS TO VALIDITY

conclusion

- We used 18 candidate symbols for the stereotype and prototype, but only 12 for the KAOS standard syntax, as it contains symbols that overload different concepts
- This overloading introduces a bias for the smaller symbol set (standard KAOS) in terms of semantic transparency and hit rate. The probability of selecting the correct symbol by chance is higher for this set.

internal

Participants all are surrogates for non-technical stakeholders and sw developers not RE experienced. To mitigate sequencing effects, symbols were randomly ordered in the questionnaires for each participant.

external

As our participants are students from the same university, they share a common cultural background. ST is often culture-specific, so their proposed and chosen concrete syntaxes were likely influenced by that background

Conclusions

- The prototype's semantic transparency was signicantly higher than the one in the standard KAOS concrete syntax
- This suggests an opportunity for improving the communication between RE experts and other stakeholders using the prototype concrete syntax proposed in this paper
- This result is in line with those obtained in similar studies for other modelling languages. Indeed, novices can be helpful in designing more recognisable symbols

Future work

- We plan to study other aspects of the PoN theory, such as complexity management, perceptual discriminability and cognitive t.
- We also plan to assess if the prototype concrete syntax has drawbacks, in particular in model construction and model comprehension, since better symbol recognition may not necessary imply better model understanding.
- Moreover, since the symbols were selected independently from each other, they do not necessarily form a consistent set, in terms of the chosen visual metaphors.
    - Thus, further research is needed to study how an inconsistent set of symbols impacts the overall model understanding.

THANK YOU

QUESTIONS?