A cognitive processing perspective on student programmers' 'graphicacy'

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Abstract. The 'graphicacy' of student programmers was investigated using several cognitive tasks designed to assess ER knowledge representation at the perceptual, semantic and output levels of the cognitive system. A large corpus of external representations (ERs) was used as stimuli. The question 'How domain-specific is the ER knowledge of programmers?' was addressed. Results showed that performance for programming-specific ER forms was equal to or slightly better than performance for non-specific ERs on the decision, naming and functional knowledge tasks, but not the categorisation task. Surprisingly, tree and network diagrams were particularly poorly named and categorised. Across the ER tasks, performance was found to be highest for textual ERs, lists, maps and notations (more ubiquitous, 'everyday' ER forms). Decision task performance was generally good across ER types indicating that participants were able to recognise the visual form of a wide range of ERs at a perceptual level. In general, the patterns of performance seem to be consistent with those described for the cognitive processing of visual *objects*.

1 Introduction

A range of ERs were used as stimuli for a range of cognitive tasks: ER decision, categorisation, functional knowledge and naming (Cox, in preparation). The aim was to assess ER knowledge representation at different levels of the cognitive system using an approach informed by picture and object recognition and naming research [2].

2 Method

Participants were 17 computer science undergraduates (14 male). The study was done in the context of a larger study [3]. Each participant completed 4 ER tasks and several programming tasks (*e.g.* program debugging[1]).

ER task stimuli consisted of 90 ERs including maps, set diagrams, text, lists, tables, graphs & charts, trees, node & arc, plans, notations & symbols,

[1] The programming task results are not reported here due to lack of space. For further details, see: `www.cogs.susx.ac.uk/projects/crusade/`

pictures/ illustrations, scientific diagrams, & icons (Figure 1). Twenty-two 'fake' or chimeric diagrams were also included in the case of the decision task. A wide range of ERs was employed so that, in future work, the corpus contains items suitable for use with a variety of subject samples.

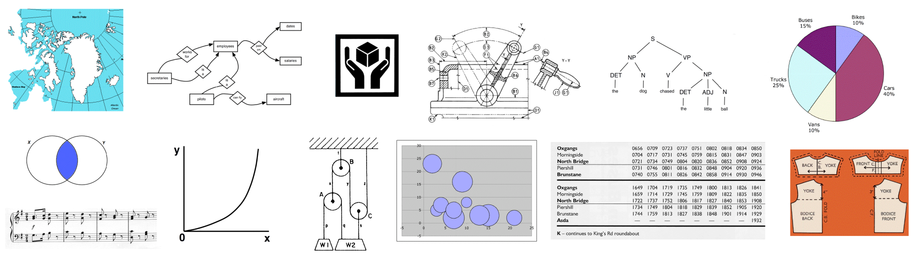

Fig. 1. Examples from the ER corpus.

The ER task sequence was *decision*, *categorisation*, *functional knowledge* and *naming*. ER presentation order was randomised across subjects. The decision task was a visual recognition task requiring real/fake decisions. The categorisation task assessed semantic knowledge of ERs - subjects categorised each representation as 'graph or chart', or 'icon/logo', 'map', *etc.* In the functional knowledge task, subjects were asked *'What is this ER's function'?* An example of one the (12) response options is *'Shows patterns and/or relationships of data at a point in time'*. In the naming task, for each ER, subjects chose a name from a list. Examples: 'venn diagram', 'timetable', 'scatterplot', 'Gantt chart', 'entitity relation (ER) diagram', *etc.*

3 Results and Discussion

Figure 2 shows that participants made fewest errors on the decision task, followed by the first semantic task (categorisation), then naming (an output task), with poorest performance on the other semantic task (functional knowledge). Inter-task correlations were also computed; only the categorisation and naming tasks were significantly correlated (r=.56, p<.05). The relatively good decision task performance indicated that the participants were able to recognise the visual form of a wide range of ERs at a perceptual level. Close-to-chance (50%) decision performance, however, was observed for graphs and charts, icons and logos and fakes. The categorisation and functional knowledge tasks measure different aspects of a person's semantic knowledge of ERs. The categorisation task can be performed on the basis of relatively broad ER features and attributes (*ie.* perceptual classification. In contrast, the functional knowledge task involves more subordinate levels of knowledge, such as mental representations of ER 'applicability conditions'. Categorisation performance was lowest for network diagrams, set diagrams and tree diagrams.

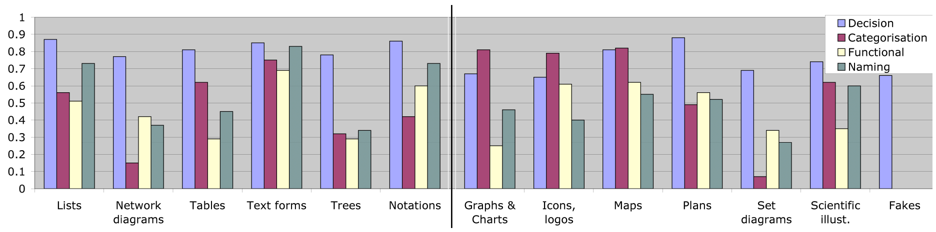

Fig. 2. ER task performance, by ER category. Mean proportion of correct responses, averaged across ERs-within-categories and participants. Programming-specific ERs (left), non domain-specific (right).

Participants showed least difficulty in categorising ‘maps’ and ‘plans’. Maps are a class of representations that have been argued to be a ‘basic’ category in the organisation of ERs in semantic memory [1]. Lists, notations and textual forms were also relatively easily categorised, understood and named. This may be due to their familiarity - they are ubiquitous, ‘everyday’ ERs. Domain-specific ERs for programming include lists, node and arrow diagrams, tables, textual/linguistic representations, trees and notations and formulae. Set diagrams, networks and trees were particularly poorly understood with very high rates of misclassification and mis-naming (Figure 2). This was surprising given that the participants were computer science undergraduates, however normative data based on wider sampling may be required in order to properly interpret the significance of this result. In general, the patterns of performance across the ER tasks were found to be consistent with those described for the cognitive processing of visual *objects* [2]. Further analyses of the relationships between performance on the ER tasks and program comprehension and debugging are planned.

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References

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