The Effect of Knowledge-of-External-Representations upon Performance and Representational Choice in a Database Query Task

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Abstract. This study examined the representation selection preference patterns of participants in a database query task. In the database task, participants were provided with a choice of information-equivalent data representations and chose one of them to use in answering database queries. A range of database tasks were posed to participants - some required the identification of unique entities, some required the detection of clusters of similar entities, and some involved the qualitative comparison of values, *etc*. Participants were divided, post hoc, into two groups on the basis of a pre-experimental task (card sort) designed to assess 'knowledge of external representations' (KER). Results showed that low and high KER groups differed most in terms of representation selection on *cluster* type database query tasks. Participants in the low group tended to change from more 'graphical' representations such as scatterplots to less complex representations (like bar charts or tables) from early to late trials. In contrast, high KER participants were able to successfully use a wider range of ER types. They also selected more 'appropriate' ERs (*ie.* ones that the diagrammatic reasoning literature predicts to be well-matched to the task).

1 Introduction

Successful use of external representations (ERs) depends upon skillful matching of a particular representation with the demands of the task. [1] and [2] provide numerous examples of how a good fit between a task's demands and particular representations can facilitate search and read-off of information. [3] provides a review of studies that show that tasks involve perceiving relationships in data or making associations are best supported by graphs whereas 'point value' read-off is better facilitated by tabular representations. This paper extends our work (reported in [4]) by researching selection accuracy and preference patterns from early to late trials (within session effects) from a study of participants' ability to select appropriate data displays for use in answering database query tasks. The tasks were based on a database of car information (e.g. fuel efficiency, engine

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size, CO2 emissions). Participants were presented with a range of different task types (identify a single entity, spot clusters, compare entities on one or dimensions, *etc*) over 25 trials. Each trial consisted of one task type (associate, cluster, compare, correlate, distinguish, identify, locate and rank). On each trial, subjects were asked to choose the particular data display representation they felt would be most useful for answering the query. The options were presented as an array of display-type icons (table, scatterplot, bar chart, *etc*). When a choice was made, an automated information visualisation engine (AIVE) then instantiated the chosen representational form with the data needed to answer the task. Each query (task) could potentially be answered with any of the display options offered, but each task type had an 'optimal' display type. Subjects then answered the query using their chosen visualization. Following a completed response, the subject was presented with the next task and the sequence was repeated. The following data were recorded: the user's representation choices; time to read question and select representation (selection); time to answer question using chosen representation (answer); and participants' responses to questions. Further details about the experimental procedure are provided in [4]. Prior to the database query tasks, participants were administered a card-sort task [5, 6] designed to assess their KERs. The tasks involves sorting and labeling a large corpus of ER examples. The aim was to study the relationship between subjects prior knowledge (or 'repertoire' of ERs) and their reasoning accuracy and representation selection performance on the database query tasks.

2 Results and Discussion

Participants were divided into two groups on the basis of a post-hoc median-split on ER card-sort cluster scores. This yielded two groups - 'typical' card-sorters (high KER) and 'more idiosyncratic' card-sorters (low KER) [4]. Overall both groups improved their response accuracy from early to late trials. The low KER group from 64% to 83%; and the high KER group from 75% early to late 84%. The 25 database task types were collapsed into 3 groups: 1. tasks requiring the precise read-off of values; 2. those involving qualitative comparison and 3. cluster tasks (involving associating entities, identifying groups of similar entities, *etc*). To assess selection accuracy, higher scores were assigned where subjects assigned representations that the literature predicts are most appropriate for the task. These include tables for read-off value tasks; bar charts for qualitative comparison; and scatter plots for cluster tasks. Representation selection from early to late trials over the different task groups showed that the low group tended to change from more to less semantically complex representations. In contrast the high KER group used a wider range of ER types in early and late trials, and selected more ERs that were predicted by the literature to be 'good' ER-to-task matches. This effect is particularly noticeable for cluster tasks. Fig. 1 shows the early and late cluster trial selection behaviour.

High KER subjects tended to use scatterplots (appropriate) in cluster tasks whereas, although low KER subjects often started with these, they later reverted

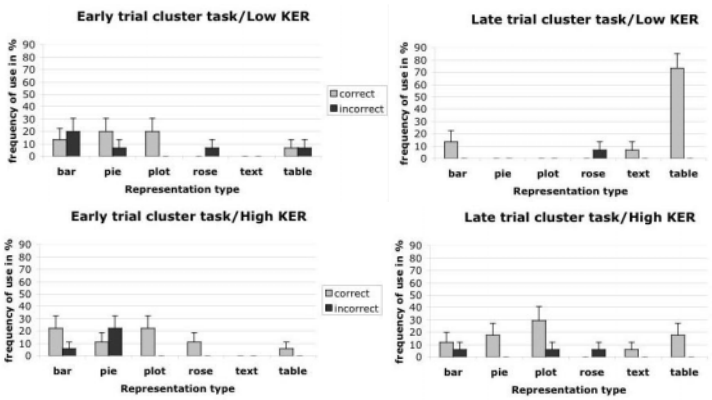

Fig. 1. Frequency with which high/low ER knowledge groups used each type of representation in cluster type tasks early and late trials (SE bars shown)

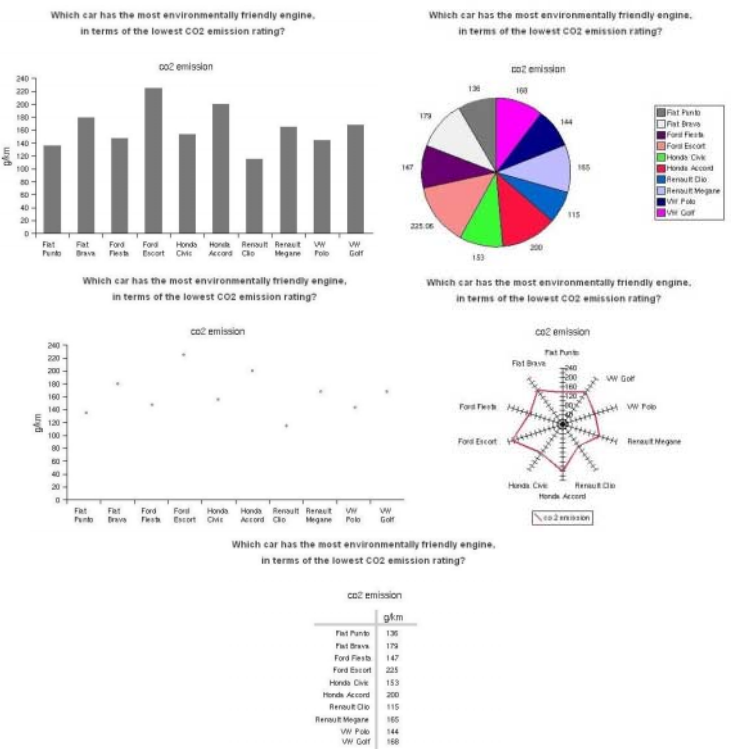

Fig. 2. Examples of AIVE bar, pie, plot, rose (sector) graph and table representations

to simpler ERs like bar charts and tables - with greater response accuracy than the higher group. In contrast the low KER group tended to change to less semantically complex ERs which some literature ([1, 2, 3]) predicts to be good ER-to-task matches. However, our results show that the selection of such ERs may not result in as great a performance decrement in those subjects as might be expected. Our research also shows that there are differences in how low and high KER groups change their selection behaviour over time where difficult tasks are presented. The high KER group tends to match ERs to tasks which have been predicted from the literature to be 'good' matches. In contrast, the low KER group tend to change to less semantically complex representations which ARE not predicted to be task-appropriate representations. The next phase of this research will investigate relationships between subjects' difficulty with particular ERs, their skill on the card sort task, and their ER classification and labelling performance.

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