Micro-behaviour measurement of graph comprehension*

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Abstract. The overall objective of this PhD thesis is to assess people's familiarity with different diagrammatic representations, in particular showing the effect of chunking (i.e., cognitive operation by which the whole information is broken down into meaningful chunks of information) through the drawing. In this paper, one study considers the drawing strategies of four diverse participants as they copied a line-graph and a bar-chart. Video recordings of the transcriptions were analysed stroke by stroke. Diverse global drawing strategies were used for the line graph whereas a similar approach was used by all on the bar-chart, but with local differences. The fluency of the participants' performance varied substantially, particular in viewing frequency of the stimuli. Differences in the strategies can be explained in terms of how they perceptually chunked the stimuli. Sample GOMS models were constructed in order to demonstrate that chunking explains the drawing strategies. The potential of using drawing transcription tasks to assess user's competence with graphs and charts is discussed.

Keywords: Chunking, competence measurement, diagrams, bar chart, line graph, graph comprehension, task analysis, GOMS, HCI, representations.

1 Thesis Topic and Approach

This paper is part of a project named Rep2Rep that is attempting to build an automated system to selected appropriate representations for individuals as they attempt to solve specific problems in some target domain [6]. Representation choice is essential for successful problem solving and learning, especially because some representations are more advantageous for representing specific problems than others. The Rep2Rep2 framework involves two aspects: (a) selecting representations that are formally adequate for the problem using AI and (b) from those picking representations that are suit an individual cognitively. This work focuses on the second. A key aspect concerning the cognitive suitability evaluation of a representation for an individual, is to assess the level of familiarity with the given representation, that is how well the representation is understood. So, quick and reliable means of assessing people familiarity with different diagrams are needed. As chunks underpin the understanding of concepts, our approach attempts to measure the chunk structures that people possess for specific diagrams. Few approaches are available (e.g., questionnaires, verbal and written descriptions) to evaluate the people competence with diagrammatic representations, so

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our main goal is to apply the "Graphical Protocol Analysis (GPA)" of Cheng & Rojas-Anaya [3] to measure people's familiarity in drawing specific diagrammatic representations. Specifically, in addition to the chunk size produced by the participants between successive stimulus visualizations, GPA allows the collection of the pauses (measured in milliseconds) between successive pen-strokes and therefore derives the hierarchical organization of the chunk in memory. Thus, this work aims to go beyond current tests that only indirectly assess familiarity.

2 Completed work

The model of display comprehension [5] claims that top-down processes (prior knowledge) interact with bottom-up information (design feature). So, in order to verify whether or not the GPA could be used as a basis of a method to assess users' familiarity or competence with particular classes of representation, a pilot study was designed using as stimuli a line graph and bar chart. We collected four right-handed participants with Master's in different subjects who completed a graph familiarity questionnaire (on a scale of 1 to 6, where 6 is high familiarity). Their scores (and subjects) are: P1=4.7 (Finance); P2=4.3 (Engineering); P3=2.9 (Literature); P4=2.3 (Law). The task was to copy each diagrammatic representation following the same procedure of Albehaijan & Cheng [1]. We found that the evidence of chunking was clear through the pattern of pauses and number of views to accomplish the copying task. Specifically, the patterns of pauses (time between pen-strokes) shown by all participants in both stimuli, reflected the hierarchical organization of the chunks in memory [2, 7]. So, long pauses at the beginning of each chunk, seem to reveal the transitions between chunk or sub-chunk boundaries and may reflect the total amount of cognition required prior to each pen-stroke (Fig. 1). Compared to the bar chart, for the line graph different drawing strategies have been observed between our participants. Furthermore, in order the verify the contribution of chunking in drawing behaviour, CPM-GOMS modelling (i.e., computational cognitive model for analysing the human performance) was applied to an idealized chunk hierarchy. A good correspondence between the pauses derived by the CPM-GOMS model and participants pause profiles supports the claim about the central role of chunking in transcription processes and competence measurement.

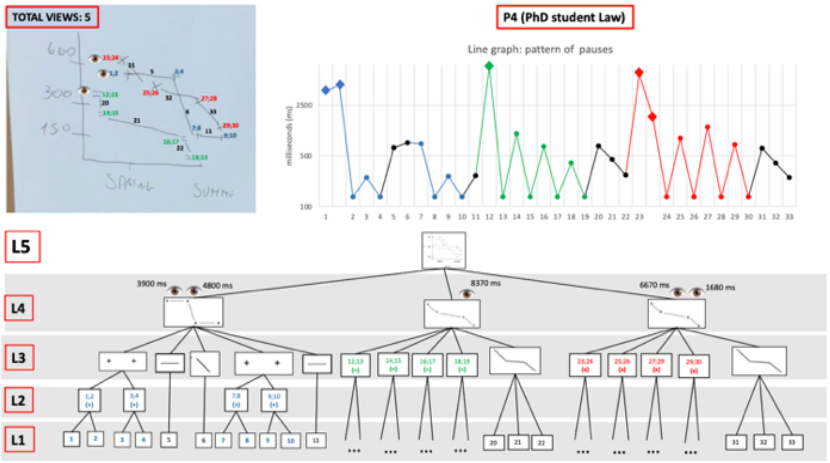

Fig. 1. Participant drawing, pause profile, and chunk process hierarchy. The length of the pauses reflects the hierarchical location of the chunk/sub-chunk, so lowest the hierarchical level shorter is the pause. Numbers and colours in the tree diagram have been used in order to have a matching with the participant drawing sequence and pause profile.

3 Future directions

The results obtained from this pilot study shows that GPA is a promising method for the competence assessments with diagrammatic representations. However, several limitations and extensions need to be considered in future. First of all, in order to derive general models of graph expertise, we need to extend the number of participants and classify their graph familiarity using a specific questionnaire on a 6-point scale. As data representations (e.g., line graph and bar chart) present spatial information represented by data points it would be worth detecting how the spatial abilities (i.e., spatial perception, spatial visualization and mental rotation) are related with chunking performance in addition to the prior knowledge. Spatial abilities are mental operations needed to encode, maintain and process a visual configuration [4], so their contribution to chunking performance should allow to broaden the understanding of the cognitive skills that underlie the competence with a specific diagrammatic representation. Furthermore, despite several drawing approaches are available in both representations, we are aiming to standardize the drawing strategies through the use of sequential animations during the stimulus presentation. Thus, by asking participants to copy the exact order of presentation of the stimuli in sequence, we may collect more coherent and reliable pauses in order to derive the hierarchical general model of chunking in both level of expertise.

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