

Comprehension Efficiency of Graphically Presented Ordered Sets¹

Christof Körner & Dietrich Albert

Abstract

Untersucht wurden Effekte sogenannter visueller Eigenschaften (Kreuzungsfreiheit, Kantenneigung, Ebenen) auf die Verständnisgeschwindigkeit von Halbordnungen, die als Hasse-Diagramme dargeboten wurden. In jedem von 3 Experimenten beantworteten Versuchspersonen Interpretationsfragen, die Vergleiche zwischen Elementen der Halbordnung erforderten. Das Wissen der Vpn variierte zwischen den Experimenten. Die Analyse der Antwortlatenzen mit einem nonparametrischen Modell zeigt, daß Kreuzungsfreiheit die wichtigste Variable ist, unabhängig von Kantenneigung und Ebenen. Erste Prinzipien für die Gestaltung von Hasse-Diagrammen konnten abgeleitet werden.

Hypotheses and Model

Upward drawings or Hasse diagrams play a central role in the (automatic) visualization of non-numerical data structures. Therefore, mathematicians and computer scientists (see, e.g., Rival, 1993) have proposed visual properties such as planarity, slopes and levels (see Figure 1). Attributes with subscript 1

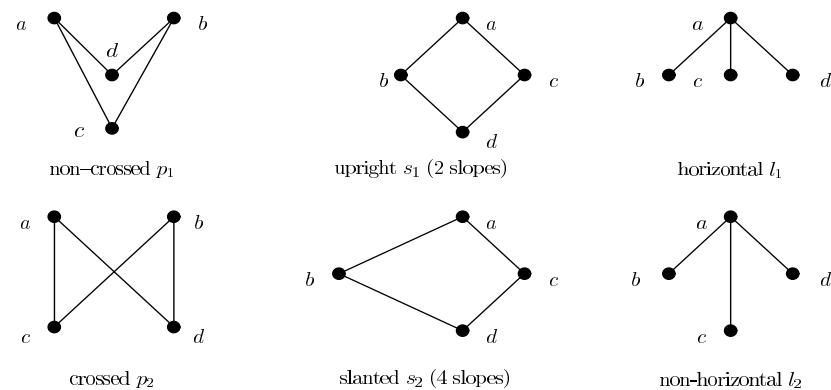


Figure 1: Visual properties (planarity, slopes, levels) and their attributes

should make comprehension of graphically presented ordered sets more efficient compared to attributes with subscript 2. Moreover, planarity should be

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more important than the other properties. Based on the work of Kosslyn (1994) and others, Körner (1998) has provided psychological arguments for these hypotheses. They can be put together in a non-parametric model which is depicted in Figure 2. Each node in this model is labelled with a triple (p_i, s_j, l_k) representing a type of diagram, e.g., (p_1, s_2, l_1) denotes a non-crossed, slanted, and horizontal diagram. The hierarchy of diagrams in the model form itself an ordered set. For example, diagram (p_2, s_2, l_2) should be comprehended least efficiently, whereas (p_1, s_1, l_1) should be most efficiently to comprehend. (p_2, s_2, l_1) and (p_2, s_1, l_2) , however are not comparable with respect to comprehension efficiency, as well as (p_1, s_2, l_1) and (p_1, s_1, l_2) . The model predictions were tested in three experiments.

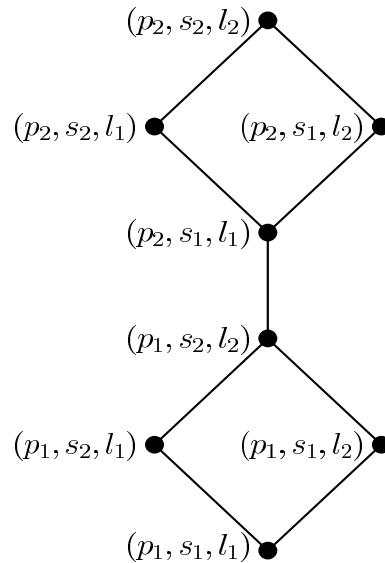


Figure 2: Model for the effects of visual properties on comprehension efficiency.

Experiments

Method

Design and Participants. The three visual properties were varied on two levels each, as depicted in Figure 1 and completely crossed (comparable to a $2 \times 2 \times 2$ design). The resulting $2^3=8$ diagrams visualized the same ordered set and differed only with respect to the visual properties. The knowledge instructed to participants varied among experiments (high, medium, low knowledge on ordered sets).

30 students of the University of Graz participated in each experiment. Participants in Experiment I served for class credit (psychology students) participants in Experiments II and III were paid.

Materials and Procedure. An ordered set consisting of nine elements and 16 ordered pairs was selected for the construction of the diagrams, i.e., the ordered information was always the same while its visualization varied according to the visual properties. For example, Figure 3 depicts the visualizations of this set as diagrams (p_1, s_1, l_1) and (p_2, s_2, l_2) .

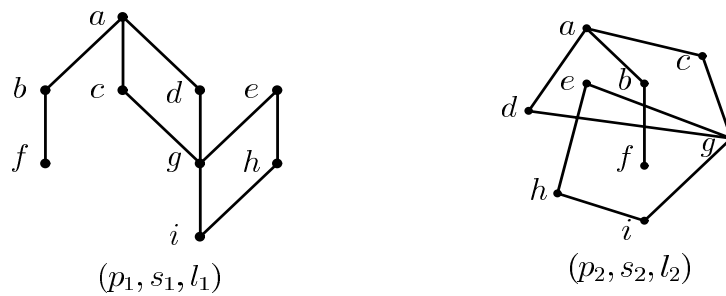


Figure 3: Diagrams (p_1, s_1, l_1) and (p_2, s_2, l_2) as examples for the 8 diagrams used in experiments.

The ordering information was presented to participants as preference relation between hypothetical persons' vacation cities. After instruction and training participants answered 10 interpretive questions which were presented together with each of the eight diagrams. The questions required comparisons between elements of the ordered set (e.g., "Does this person like to travel to Madrid and Rome more than to Lisbon?"). The latencies of participants' responses were recorded as a measure of comprehension efficiency.

Results and Discussion

Due to instruction and practice the percentage correct was greater than 96% in all experiments. The following analysis focused on medians of responses to correctly answered interpretive questions per diagram. The non-parametric model can be tested with the Goodman-Kruskal γ . The index reflects the number of latency pairs concordant with the hypothesis minus the number of pairs non-concordant, normalized by the number of pairs for which a hypothesis exists. The index can range in $[-1, +1]$ with +1 indicating a perfect relation between prediction and data, and a value of 0 denotes no relation.

γ values for 25, 25, and 24 (out of 30) participants were positive in Experiments I to III, respectively. A mean γ value computed across averaged latencies of participants of an experiment yielded values of .85**, .77**, and .92**, respectively which indicated excellent model predictions of the data for all experiments. In Figure 4 these latencies are drawn aside of the nodes representing the respective diagrams in the hierarchy of the model.

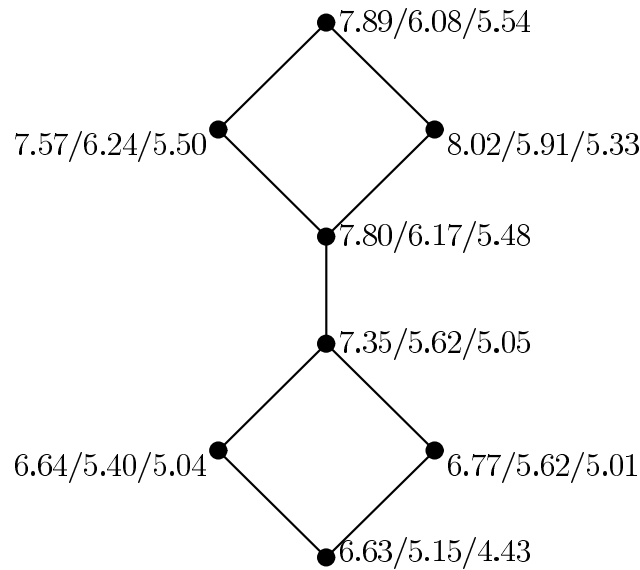


Figure 4: Mean median latencies in s (Experiment I/Experiment II/Experiment III) per diagram drawn according to the model.

The analysis confirms our assumption that visual planarity is the most influential property. Even with simple interpretive questions and readers having not much knowledge about ordered sets (as in Experiment III) visual planarity is a property even more desirable than slopes and levels.

It is frequently the case that not all of the desirable properties can be achieved simultaneously in a diagram. Therefore, a diagram designer should try to first realize non-crossed diagrams before trying to realize other visual properties.

References

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