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Use of Spatial Transformations in Graph Comprehension

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Introduction

Current theories of graph comprehension are largely silent about the processes by which inferences are made from graphs (Freedman & Shah, 2002; Pinker, 1990), although it is apparent that people are able to make such inferences. In Trickett & Trafton (2004), we proposed that people use spatial reasoning, in the form of spatial transformations (Trafton et al., in press) to answer inferential questions. This paper is an extension of our earlier study, in which we standardized the graphs presented, so that the distance from the x and y axes was identical for all conditions, we removed typing time from the RT measure. Finally, we expanded the experiment with an additional "middle extension" condition.

Method

8 graduate students and faculty at GMU participated. Participants were shown 40 unlabelled line graphs presented in random order, 10 in each of 4 conditions. They were asked for the value of the y axis at a point on the x axis. The 4 conditions were: read-off (arrow beneath line), near (arrow slightly beyond line), middle (arrow a greater distance) and far (far beyond end of line) (see Figure 1).

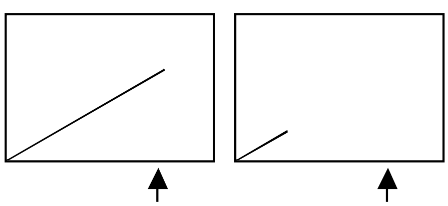

Fig. 1: Schematic of readoff (left) and far (right) conditions.

The readoff condition required no spatial transformations. However, in the near, middle and far conditions, we hypothesized that participants would mentally extend the line (i.e., use spatial transformation) to locate its intersection with the perpendicular from the red arrow. Spatial transformation theory predicts that longer extensions take longer; thus, we predicted that participants would be fastest in the read-off (no extension) condition, increasingly slower in the near and middle conditions, and slowest in the far (longest extension) condition. We also predicted that accuracy would decrease with increased use of spatial transformations, as people must move further from "anchor points" on the graph to obtain needed information—i.e, most accurate in the read-off condition, decreasingly accurate in the near and middle conditions, and least accurate in the far condition.

Results and Discussion

We measured accuracy as the absolute value of the correct response minus the participant's response. Response times (RT) represent the time taken to reach an answer.

Consistent with our hypothesis, participants were most accurate on the read-off task, decreasingly accurate on the near and middle tasks, and least accurate on the far task, repeated measures ANOVA $F(3, 15) = 12.43$, $p < .01$, linear trend $F(1, 5) = 13.93$, $p < .05$.

RT data also supported our hypothesis. Participants were fastest on the read-off task, increasingly slower in the near and middle tasks, and slowest on the far task, $F(3, 15) = 7.44$, $p < .05$, linear trend $F(1, 5) = 10.99$, $p < .05$. The linear trend is consistent with the idea that a longer extension takes more time to execute than a shorter one. If this is true, it should take a measurable amount of time more for each extension. In order to calculate how long each extra extension took, we did a linear regression, using the distance the participants had to extend the line (recall that the distance along the x and y axes was constant). This analysis was significant, $r = .43$, $p < .01$. The analysis yielded the following formula: Response Time = 4.8 + .63, where 4.8 seconds is the baseline time to read information from the graph and .63 is the amount of extra time required to extend the line each centimeter distance required. This result supports our hypothesis that participants used spatial transformations, by indicating a systematic relationship between response time and the distance mentally traveled. As participants had to draw longer mental extensions to the graph, their response times systematically increased. Thus, we propose that a comprehensive theory of graph comprehension should accommodate spatial reasoning.

References

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