The Effect of Depth Information on Inferring Cross-sections

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Introduction

Cross-sections of objects are ubiquitous in domains such as medicine, biology, geology, architecture, and engineering. For example, medical images, such as MRI, represent two-dimensional (2-D) planar cross-sections of the 3-D body. Although cross-sections are pervasive, little is known about the cognitive abilities involved in interpreting cross sections or imagining what the cross section of a 3-D object will look like.

Depth Information and Cross-Sections

In previous research we have found that people have difficulty inferring the appearance of a cross section of a 3-D object displayed on a computer screen (Keehner et al., 2004.). One possibility is that this reflects difficulty in perceiving the 3-d structure of the object. Another possibility is that the difficulty is more cognitive, i.e., people encode the structure of the 3-D object correctly, but have difficulty with the process of mentally slicing an internal representation of the object.

If the difficulty is perceptual, additional perceptual depth cues in the external display should improve performance by providing better information about the spatial relationships between internal features of the object. In this experiment, we examined the effects of motion-based depth cues (e.g., motion parallax) by comparing performance of participants who received animated versus static displays of a 3-D object. We also examined the effects of binocular depth cues by contrasting the effects of stereoscopic viewing (with shutter glasses) to monoscopic viewing of the 3-D object.

Method

Eighty undergraduates performed 18 trials of a cross-section task. On each trial they were shown a picture of a 3-D anatomical object (a tooth) with a line drawn through it. The task was to imagine the cross section that would result if the tooth was sliced at the line and to chose the correct answer from 5 alternatives (see Figure 1) While performing this task, participants saw either a rotating animation or static view of the display, with or without shutter glasses (2X2 between-subjects design). Individual differences in mental rotation, perspective taking and abstract reasoning were also measured.

Results and Discussion

The depth cues provided by motion parallax and stereoscopic viewing did not significantly benefit performance. A 2 (Animation) x 2 (Stereopsis) between-subjects factorial ANOVA indicated that neither animation, stereoscopic viewing, nor the interaction of these factors had any significant effect on cross-section task performance ($F(1, 76) < 1$ in all cases).

Analyses of individual differences indicated that performance on the cross-section task was correlated with mental rotation ($r=0.478$), perspective taking ($r=0.448$), and abstract reasoning ability ($r=0.382$). Partial correlations, controlling for abstract reasoning ability, indicated significant correlations between the cross-section task and the spatial ability measures, mental rotation ($r=0.3836$) and perspective taking ($r=0.3335$).

These results indicate that difficulty inferring cross sections is not strictly a perceptual problem of encoding 3-D structure from an external display. Increasing depth cues does not improve performance. Instead, the bottleneck is at the cognitive level, and spatial ability appears to be more helpful for correctly inferring cross-sections.

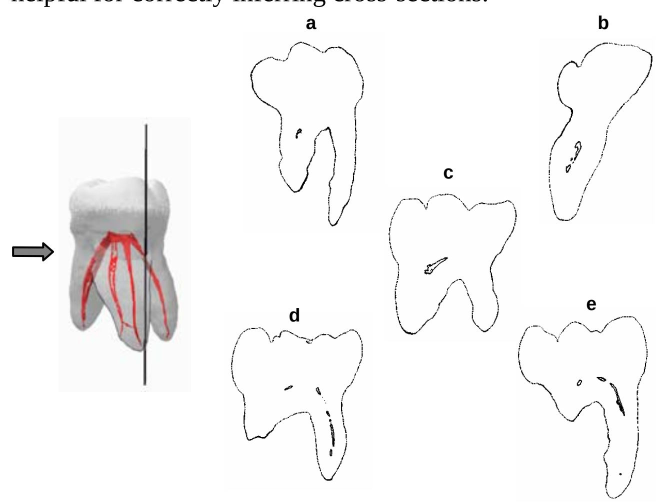

Figure 1: A sample item from the cross-section task. The correct answer is (a)

Acknowledgments

This research was supported by NSF ITR grant #EIA-0313237, NSF IGERT grant #DGE-0221713, and DOE fellowship #DE-AC05-06OR23100.

References

Keehner, M., Montello, D. R., Hegarty, M., & Cohen, C. (2004, July). Effects of interactivity and spatial ability on the comprehension of spatial relations in a 3D computer visualization. Presented at the annual meeting of the Cognitive Science Society, Chicago, IL.