Overcoming Graphical Fixedness: Scaffolding Comprehension for Unconventional Graphs

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Abstract. How do we make sense of a graph we've never seen before? Kosslyn [1] suggests we instantiate a hierarchically-organized graph schema. But what schema is triggered for novel representations? Pinker [2] speculates readers instantiate a "general graph schema" likely based on the coordinate system and "predominate graphical forms". But what information does this schema contain, and how does it interact with prior knowledge of other graphical forms? Here we investigate the graph schema by exploring how learners read an unconventional representation. We ask: (1) What strategies do learners employ to make sense of an unconventional graph? (2) What explicit information might scaffold (self-directed) comprehension? (3) Can structuring graph-reading tasks as insight problems help overcome contradictory prior knowledge? (4) What is the time-course and of mental model formation? (5) What inscriptions serve as the graphical framework, triggering a particular graph schema?

Keywords: Graph Comprehension, Statistical Graphs, Scaffolding Learning.

1 Background

As powerful as graphics may be in their communicative efficiency, they needn't be *immediately* easy to understand [3]. This underlies much research in InfoVis: developing sophisticated representations for specialized tasks. The result is novel, unconventional representations computationally-suited to particular tasks, with interpretive challenges untrained readers. In this project we use a simple but unconventional graph (Figure-1) The Triangular Model (TM) of Interval Relations [4] to explore how individuals make use of prior knowledge when reading new graph forms. We suspect the factors that drive ease of use in general, may *hinder* comprehension of unconventional representations. For the TM graph, our results suggest readers' expectations for the structure of the coordinate system interfere with their ability to follow graphical cues provided by the graph's diagonal gridlines: learners mischaracterize the system as Cartesian. We believe the substantial body of literature on insight problems (e.g. [5]) provides a promising direction for how we might support learners in overcoming this "graphical fixedness".

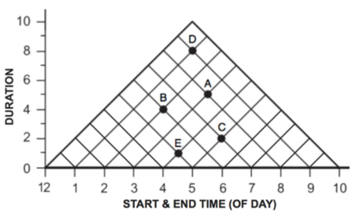

Figure 1: TM Graph

2 Summary of Studies and Methods

To address these questions, we've conducted three studies and planned two additional, utilizing qualitative and quantitative methods including: observation, interview, participatory design tasks, computer-based comprehension tasks, graph production tasks, eye-tracking, and participant narration of video-recorded mouse/gaze data.

Study One & Two: Observing Graph Reading & Evaluating Scaffolding. The results of our first two studies are reported in [6] to be presented at Diagrams '18. We began by asking the question: What strategies do students employ to make sense of an unconventional graph? We observed students solving scheduling problems with the Triangular Model (TM) graph, before challenging them to design instructional aids. We found most students mistakenly interpreted the graph as having a Cartesian coordinate system. [6]. In the follow-up interview, students produced both text and image instructions. In Study Two, we evaluated these student-suggested scaffolding techniques. Data from 316 STEM undergraduates revealed none of the scaffolds were sufficient to realize the computational efficiency of the TM [6]. Only an interactive image resulted in accuracy significantly better than the no-scaffold control. However, through subtle differences in materials we found students whose first question posed a 'mental impasse' (no correct answer if they misinterpreted the graph as Cartesian) had significantly improved performance. We suspect the novelty of the TM graph was insufficient in directing readers' attention to the salient differences between the graph and its more conventional alternative, resulting in a Cartesian misinterpretation. However, the mental impasse provided by questions in one set of materials directed readers' attention to their mistake. We address this hypothesis in Study Three.

Study Three: Evaluating Implicit vs. Explicit Scaffolding. In a factorial design we compared students' TM graph accuracy with a combination of explicit (none-control, static text/image, interactive image) and implicit (non-impasse-control, impasse) scaffolds. Data from 180 STEM undergraduates reveal that structuring problems to provide a mental impasse *did* significantly improve performance, though not more effectively than explicit scaffolds. We found substantial variance in accuracy, suggesting individual differences may play an important role in strategy. We are presently analyzing mouse-path recordings and inviting an additional group of students to provide talk-aloud narration of their mouse-path recordings. We are also gathering eye-tracking data for 60 students to explore the graph-inspection strategy by scaffold.

Study. Four: Timing the Mental Impasse. Next we explore the timing of mental model formation. In studies 1-3, we found students form an interpretation the graph while solving the first problem, holding steady throughout the problem set despite implicit cues they are making errors. We hypothesize the presentation of an impasse must be timed with this initial model formation. To test, we utilize the materials from Study 3 and assign STEM undergraduates to one of four timing conditions: (1) all-impasse, (2) first-impasse, (3) late-impasse and (4) no-impasse. We predict that to be effective, the impasse must be presented on the first question, while the students are forming a mental model of the graph system (Figure 2).

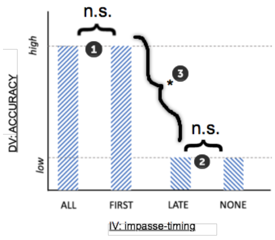

Fig 2. Study 4 Expected Results

Study Five: Defining the Graphical Framework. Finally we explore what features trigger a particular graph schema. We present readers with a TM graph featuring differing gridline/axis designs (Figure-3). We hypothesize the axes (not gridlines) trigger instantiation of a particular schema, therefore expecting significantly better performance by participants viewing diagonal (Figure 3 *right*) axis design.

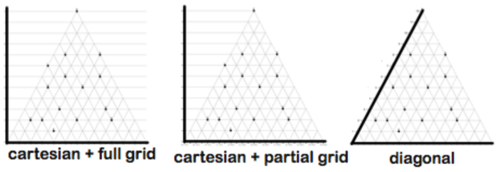

Fig 3. Alternative Axis/Grid designs

3 Doctoral Symposium Goals

As I will defend my proposal shortly after the workshop, I wish for this mentorship to help ground my methodologically detailed plan in the broader context of current research in graph comprehension. I wish to connect with senior scholars to consider the relevance of this area of research in the landscape of research on external representations, and substantially strengthen the theoretical grounding of my specific research questions, shaping how I form the dissertation into a substantive basis for an ongoing research programme.

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