Cognitive Style's Effects on User Task Performance in Network Visualisations

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Abstract. With the increasing importance of visualisation in being able to understand large sets of data, there is a growing body of research on how individual differences can influence a user performance in tasks using network visualisations. Individual differences in how users interact with and respond to visualisations presents an opportunity to inform how we construct visualisations. In this study, we chose to explore the effect of cognitive style on users' performance in network visualisations. Three psychological constructs were used to account for individual differences; the Verbal-Imagery Cognitive Style, Rational-Experiential Inventory and Wholist-Analytic Cognitive Style. Using a sample of university students, we measured participants accuracy, effort, time, and efficiency to complete three separate tasks on network visualisations. Overall, the results of the study show evidence that cognitive styles account for some individual differences in user's visualisation performance.

Keywords: Cognitive style, Network visualisation, Evaluation, Individual difference

1 Introduction

Conventional means of measuring visualisation performance such as time and accuracy only capture a part of individual difference, therefore using a psychometric measure allows us to see if there are any additional factors influencing visualisation perception [6, 12].

1.1 Current Study

As there are not many studies in the field visualisation that have utilized cognitive styles as a measure of individual differences we seek to explore if there is any influence cognitive styles can have on comprehension, accuracy, speed, or efficiency across the three visualisation tasks [5]. Based on the three cognitive styles and prior research, there are three hypotheses to explore. First, in the Rational Experiential Inventory (REI), participants who score higher in experiential cognitive style will correlate to lower accuracy in the visualisation task [5, 11, 13]. Second, in the Verbal Imagery Cognitive Style (VICS), the visualizer cognitive style will correspond to a better performance in the visualisation tasks [4, 5, 10]. Thirdly, in the Cognitive Styles Assessment-Wholistic Analytic (CSA-WA), participants who score higher in the analytic style will also correlate to higher accuracy and performance in visualisation tasks [7, 15]

2 Method

2.1 Participants

Participants (n = 28) were recruited from information technology university students with ages ranging from 22 to 31 (M = 27.29, SD = 2.14), out of the 28 participants only one was female.

2.2 Cognitive Style Measures

CSA-WA. The CSA-WA is 80 items that measure or survey both analytic and wholistic cognitive styles, recording the time and accuracy of the participants' responses [8].

VICS Test. The VICS contains 232 survey items with half being verbal and the other being imagery stimuli [8].

REI. The REI-40 is comprised of a 40 item survey with 20 questions weighted towards experiential cognitive style and the other towards rational cognitive style [1].

2.3 Visualisation Efficiency

Combining the response time (RT), response accuracy (RA) and the mental effort (ME) in Formula (1) we can obtain a measure of visualisation efficiency. As suggested by Huang, Eades [2], the measure of visualisation efficiency was used as a measure of cognitive load.

$$E = \frac{zRA - zME - zRT}{\sqrt{3}} \tag{1}$$

2.4 Procedure and Visualisation Tasks

Participants were asked to give their consent, then three cognitive style tests were administered, and the three visualisation tasks were given after a brief tutorial example. The stimuli were 120 node-link diagrams that were drawn with a commonly used force-directed algorithm from 120 randomly generated networks [3, 14]. Network visualisations, when drawn to minimize crossings and possess a low to moderate density, can more effectively measure the user's performance visualization [2]. The three tasks chosen were:

1. Shortest Path: Involved the participants finding the shortest path between the two highlighted nodes in the figure.
2. Common Neighbour: Tasked participants to find how many common neighbours the highlighted nodes have.
3. Degree: Asked the participants to compute the largest degree of the three highlighted nodes

3 Results

Table 1. Pearson Correlation

Measure	Wholistic Analyst Style	Rational Cognitive Style	Experiential Cognitive Style	Wholistic Cognitive Style	Imagery Cognitive Style
Degree Task Efficiency	-.483*	-.304	-.492**	.294	.396*
Degree Task Effort	.238	.312	.557**	-.318	-.230
Degree Task Time	-.146	-.209	-.307	.316	.268
Degree Task Accuracy	-.472*	-.289	-.461*	.284	.392*
Common Neighbour Effort	.284	.482**	.525**	-.378*	-.245
Common Neighbour Time	-.123	.155	-.163	.456*	.246

*p < .05. **p < .01

Tasks or measures with non-significant correlations were removed from the table.

4 Discussion and Conclusion

The findings of the study show that there is some correlation between the participants' visualisation task performance and their cognitive style, with evidence for the first two hypotheses. The three cognitive styles tested were compared as combined measure such as rational-intuitive, or individually as either rational or intuitive. The results also show that the individual cognitive styles showed a greater correlation to performance than the combined measures (See Table 1). Cognitive styles also demonstrated greater relationship to time, accuracy, and effort measures with only on Degree Task Efficiency providing any significant correlations to the cognitive styles. Furthermore, cognitive styles such as wholist or experiential which operate in opposition to visualisation performance showed a greater negative correlation in time and effort spent on some tasks. The cognitive styles such as imagery which operate in the same domain as visualisation showed a greater accuracy in certain tasks.

The results of the study are encouraging as they show that cognitive styles play a role in understanding how individual differences in users can impact how they interact with a visualisation. There are several implications in computing, if the sample of users is known to prefer using visual cognitive style, it allows us to design visualisation or learning material that will provide greater engagement and show a greater degree of understanding. Although the current study is exploratory, the results may provide an opportunity for a study with a larger sample which would allow more comprehensive statistical analysis.

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