Visual Analytics: Computational *AND* Representational Data Processing to Support Analytic Rigor

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Background: The Call for Visual Analytics

It is increasingly unclear how useful our data analytics technologies are to front-line operators, especially as uncertainty, complexity, time pressures, and workload increase. As these increases are a continuing trend in a wide range of settings, the importance of being useful during these difficult situations is also growing. In trying to address these challenges, the US Department of Homeland Security chartered the National Visualization and Analytics Center (NVAC) in 2004 to set the vision for a visual analytics agenda, which came to encompass the following (Thomas & Cook, 2005):

- *Analytical reasoning techniques* that enable users to obtain deep insights that directly support assessment, planning, and decision making
- *Visual representations and interaction techniques* that take advantage of the human eye's broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once
- *Data representations and transformations* that convert all types of conflicting and dynamic data in ways that support visualization and analysis
- Techniques to support *production, presentation, and dissemination* of the results of an analysis to communicate information in the appropriate con- text to a variety of audiences.

This agenda highlights the importance of conceptualizing our solutions as symbols with with operators try to learn something about the world. To do this, the designer must (1) accurately map changes in the world to changes in its output display (e.g., words, numbers, lines, shapes), and (2) understand how changes in the display are interpreted by people. This dual mapping is required to make sense of any symbol or field of view (Bennett & Flach, 2011), and is shown in Figure 1. When representations are redesigned so that this second mapping is supported by visual processing, it has been shown to produce better decision-making, especially in high-complexity situations (Guerlain et al., 1999; Rayo et al., 2015; Watson & Sanderson, 2004).

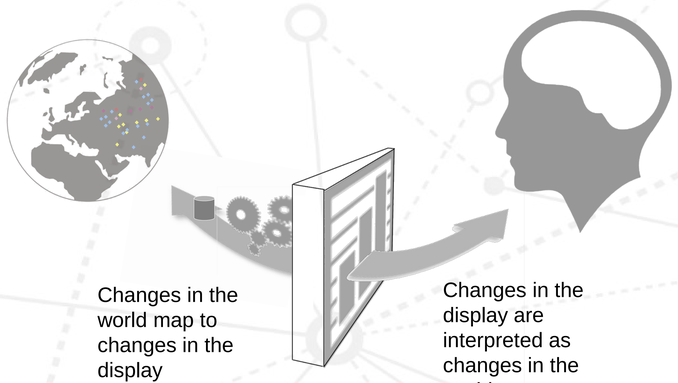

Figure 1: Symbol Mapping principle applied to digital display

Filtering vs. Highlighting and Prioritizing

However, in practice, it is commonly seen that when computational processing increases to meet the demands of larger data sets, less data becomes available to the operator (see Figure 2). These computational solutions become increasingly opaque as to how they arrived at their ultimate conclusion, and effectively filter the data available for to operator, making the solution less informative. This is especially true of clustering algorithms and neural net techniques, in which it is impossible to discern the rationale behind the machine's decision. This filtering of data makes it difficult for the operator to "see past" the technology to make well-calibrated decisions about the world. By contrast, visual analytics solutions use organization of the visual field to highlight and prioritize data, ultimately increasing informativeness.

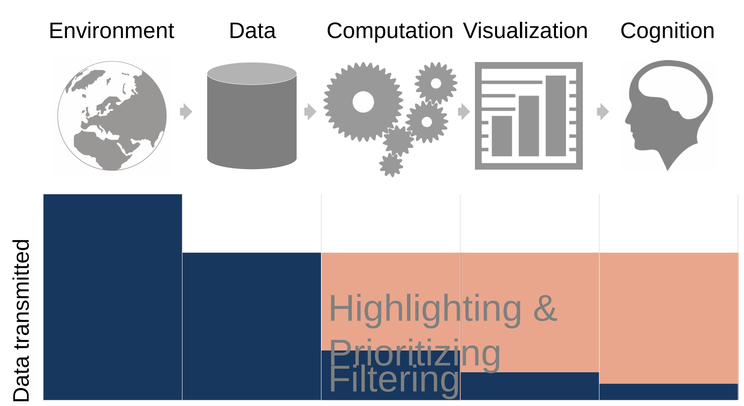

Figure 2: Data availability due to filtering vs. highlighting

Improving analytic rigor by presenting process data

In our upcoming longitudinal interventional ethnography, we will be studying how different decision-support solutions utilizing various combinations and strengths of computational and representational processing can accelerate expertise in analytic rigor while performing intelligence analysis. We will be studying multiple intelligence cells with novice analysts to better understand the following:

Research Question 1: What aspects of rigor representations accelerate expertise in the analyst?

- H1: Viewing multiple dimensions of rigor simultaneously will support accurate assessment of analysis rigor
- H2: Viewing continuous measures of rigor dimensions will be superior to categorical measures
- H3: Facilitating interrogation of rigor representations will better support accurate assessment of display applicability, and therefore better assessment of analysis rigor

Research Question 2: What aspects of rigor representations support a manager's ability to ascertain the quality of an analysis product?

- H1: The same aspects of the representation that accelerate expertise will also increase ability of the manager to ascertain analysis product quality.

Methods

We will be running four 4-person intelligence cells for one year. Each cell will be asked to complete reports on multiple Requests for Information (RFI's) on topics ranging from preparedness for a potential Zika outbreak to the viability of a future spacecraft. Rigor for each report will be measured via a rigor metric rubric (Zelik, Patterson, & Woods, 2007), and performance will be compared between cells receiving visualizations of their process and those that do not. Additional analysis will be conducted on how the amount of computational and representational processing in the visualizations affects expertise acquisition and analytic rigor. Examples visualizations with low and high amounts of computational processing are shown in Figure 3. Both are meant to cue the analyst on how narrow or broad their current analysis is, which is a strong determinant for analytic rigor (Zelik, Patterson, and Woods 2007). Whereas the first uses simple arithmetic to calculate proportions of behaviors, the right calculates and plots network properties of the analyst's search process, and shows the search networks themselves (bottom right pane) upon request.

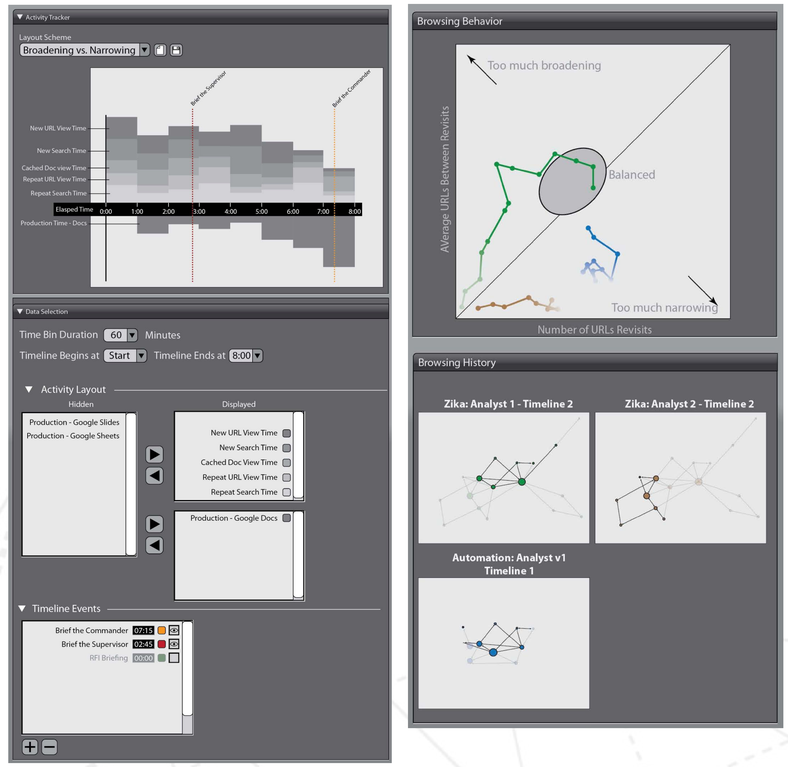

Figure 3: Process visualizations with low (left) and high (right) amounts of computational processing

Expectations and Future Directions

It is our expectation that expertise will be accelerated by presenting these feedback visualizations to the analysts. Because our study is longitudinal, we will have opportunities to change the design of the feedback given to the analysts, and using their initial performance as feedback for future design iterations. We also plan to introduce feedback that does not contain visualizations, but only the output of the performance algorithms.

References

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