Putting Annotations to the Test

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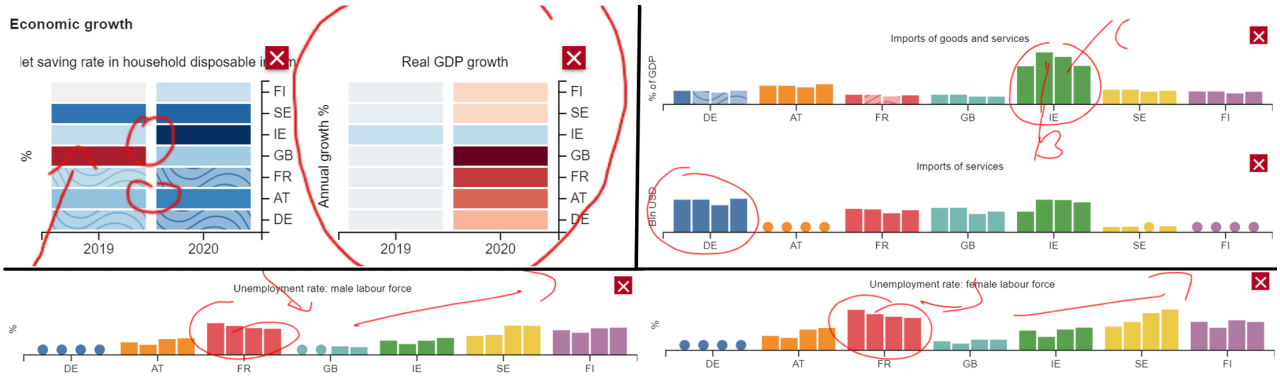

Figure 1: *Partial view of our visual analytics system with annotations created by participants during the second task of our pilot study. They circled areas of the visualization they considered relevant for the task or drew arrows to highlight a particular data point of interest.*

Abstract

When users work with interactive visualization systems, they get to see more accessible representations of raw data and interact with these, e.g. by filtering the data or modifying the visualization parameters like color. Internal representations such as hunches about trends, outliers or data points of interest, relationships and more are usually not visualized and integrated in systems, i.e. they are not externalized. In addition, how externalizations in visualization systems can affect users in terms of memory, post-analysis recall, speed or analysis quality is not yet completely understood. We present a visualization-agnostic externalization framework that lets users annotate visualizations, automatically connect them to related data and store them for later retrieval. In addition, we conducted a pilot study to test the framework's usability and users' recall of exploratory analysis results. In two tasks, one without and one with annotation features available, we asked participants to answer a question with the help of visualizations and report their findings with concrete examples afterwards. Qualitative analysis of the summaries showed that there are only minor differences in terms of detail or completeness, which we suspect is due to the short task time and consequently more shallow analyses made by participants. We discuss how to improve our framework's usability and modify our study design for future research to gain more insight into externalization effects on post-analysis recall.

CCS Concepts

• ***Human-centered computing*** → ***Empirical studies in visualization; Visualization systems and tools;*** *Visual analytics;*

1. Introduction

Visualization, at its core, aims to provide tools to gather insight from data. Visualization's primary means of creating insight are to provide accessible ways to transport (abstract) pieces of information to the user, e.g. information about value distributions, feature relationships and more. In that regard, visualization primarily considers *external* information, whereas *internal* information such as previous knowledge or hunches are often left out. Externalization presents an opportunity to support users by providing external memory capacity and also letting users experiment with different representations [Kir17]. Externalizations in the form of annotations are not new to visualization, but advances in hard- and software have increased general interest in the topic [LIRC12], though questions related to analysis quality, recall and user workflow are not

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completely understood. With *ActiveInk*, Romat et al. [RHRH*19] have implemented an externalization system that seamlessly incorporates both interactions and annotations via pen & touch and analyzed how this enables active reading behaviors. Kim et al. [KHRL*19] investigated how note-taking differs between several approaches, finding among others that users created more notes with their prototype and often linked annotations to data. We implemented a visualization-agnostic externalization framework that should serve as a basis for future studies to investigate the externalization design space and effects on different analysis facets like recall or quality. To assess the usability of our framework and test our study design for effects on analysis recall, we conducted a small pilot study.

2. Externalization Framework Design

The design of our web-based externalization framework is based on interface concepts prevalent in digital art software and other related works [KHRL*19, RHRH*19]. Our framework consists of an annotation canvas layered on top of the visualizations and operates in *modes* that each define which interactions are possible. In total, the framework provides four modes: *layer*, *brush*, *shape* and *edit*. These modes let the user manage layers, which bundle an application state and related annotations, draw on the canvas, add shapes and text or modify annotations on the canvas, respectively. The user can switch between these modes via buttons or keyboard shortcuts, though our framework is intended for use with digital pens.

3. Pilot Study

As a basis for our pilot study, we implemented a visual analytics system that consists of both simple visualizations and more advanced visualizations (see Figure 1). To make the study accessible for many people, the system uses data that most people should have some understanding about: statistical indicators for several countries for the years from 2014 to 2021. This data was sourced from the OECD [OEC23], available as country statistical profiles. The visualization system and annotation framework are both web-based and were used by participants via a Microsoft Surface Pro 4 with a detachable keyboard and a digital pen.

3.1. Study Design & Participants

We gave participants two tasks, each with a structurally similar question, but only let them use annotation functionalities for the second task. The first task asks participants to find indicators where European and non-European countries might differ and provide concrete examples. The second task asks them to find indicators that show where European countries may have been impacted by the COVID-19 pandemic and provide concrete examples. A task consists of a short introduction phase that includes the question that participants should try to answer, an analysis phase for exploration ($\approx$ 10 min) and a reporting phase where they must present their findings ($\approx$ 3 min). Each session lasted around 40 minutes and we recorded both the computer screen and audio and asked participants to think aloud while working on the task. We were able to recruit three participants, two from our own institute and one from a different university. All of them had much experience with visualization and at least some experience with digital pen devices.

3.2. Results

Participants' interactions showed that its possible to use our framework successfully, even with little to no training. However, having to switch between modes resulted in mistakes, with participants forgetting to switch to another mode before interacting with the visualizations. While this can likely be alleviated by training, it can present an opportunity to improve the design. Two participants commented that it would be nice for the application to automatically detect whether the pen is used and switch to the brush mode automatically. These findings are similar to observations by [RHRH*19] regarding to their ink modes: participants made more mistakes when they were required to choose a tool before an interaction. Additionally, participants made no use of the shape mode since drawing with the pen was faster and required less interactions.

Comparing the verbal finding summaries between task one and two, we found only minor differences like participants failing to mention all findings recorded during the analysis phase in task one, and mostly leaving out negative findings. One participant lost their annotation layer by accident and their subsequent summary only contained fragments of their previous analysis. This finding is in line with a prevalent notion that an advantage of externalizations is their capability to improve or *extend* people's memory [Kir17]. It may also be the case that expecting to have annotations for the reporting phase results in poorer recall than it would otherwise, which could be an interesting topic for future research. During the study sessions, we also observed that participants were a bit reluctant to report findings they already mentioned during analysis. This was especially prominent when a participant only explored a small portion of the data, i.e. it was easy to remember the insights they gained and there was almost no time between verbalizing the insight during analysis and doing the same in the reporting phase. Finally, we saw that participants were initially overwhelmed by the number of indicators, 109 in a total of 22 categories, available in the dataset. While this was intentional so as to provide data with enough breadth to perform a more detailed analysis, combined with the short time span available, this can present problems. Participants may choose to spend more time browsing superficially or only analyze a tiny set of indicators.

4. Conclusion and Future Work

To investigate effects of externalizations, we implemented an externalization framework and tested its usability in a small pilot study. In addition, we evaluated a study design to explore effects of annotations on analysis recall, where participants were asked to provide verbal summaries with concrete examples, once with and once without annotations. Overall, this setup seems promising, but we plan to either give participants more time to gather insights or use an interference task to make recall more challenging. While using a think-aloud protocol helped us gain insight into usability issues and the thought processes of participants, we suspect it may decrease their motivation to give detailed answers that include findings they already reported during the analysis phase. Using these observations, we plan to improve our framework and study design and conduct a new study to investigate effects of externalization on analysis recall in greater depth.

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