Using Visualization Software to Understand Complex Healthcare Interactions in Heterogeneous System Communities

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Abstract – *This research examines the role of visualization on the understanding of complex interactions that take place in large-scale communities of interdependent systems that comprise Health Information Exchanges. In particular, this paper uses a survey mechanism to examine the effectiveness of Mohawk College's Visualizer software on human understanding of the transmittal of electronic health record information in such communities of systems. The survey found that health informatics professionals were positively poised regarding the Visualizer's ability to facilitate understanding of vendor products in complex architectures, its ability to assist in interpreting audit messages, and its ability to facilitate the illustration of audit information. Respondents also reported a highly statistical difference in their understanding of the transmittal of electronic health record information when using the Visualizer software as opposed to an architectural diagram.*

Keywords: Health Informatics, Visualization, Usability, Audit Messages, Electronic Health Records

1 Introduction

According to Knodel et al., "Visualization is a sound means to facilitate understanding of complex correlations and offers a broad variety of concepts." [5]. As such, Visualization can be used as a tool to understand complicated relationships between different systems that work together in large-scale heterogeneous communities [4].

In healthcare, software components from numerous vendors frequently work together in communities called Health Information Exchanges (HIE's) to provide services to a variety of clients in that community. Clients can be entities such as patients, labs, primary care physicians, specialists, and hospitals. In addition, these communities can also exchange data with systems from different communities.

Tools such as Mohawk's Visualizer software can provide important information about the complicated interactions between the heterogeneous components from the different vendors in these health information exchanges. The Visualizer works by showing the connections between the components and by animating the exchange of information [2,9] using results derived from health care security audit messages [8].

Figure 1 shows a screen capture of the Visualizer with two Health Information Exchanges that take part in a Cardiologist referral scenario.

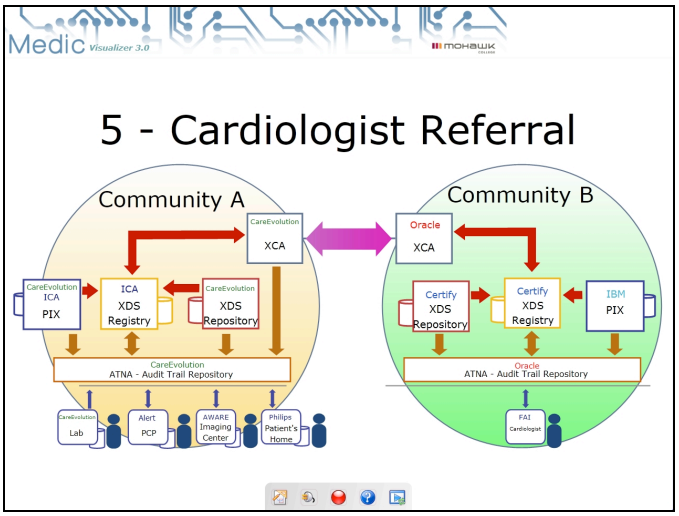

Figure 1: Mohawk's Visualizer

Mohawk College has employed the Visualizer to showcase the interactions in vendor communities at small-scale interoperability showcases such as the COACH conference in Canada as well as at significantly larger gatherings such as the HIMSS conference in the United States [15].

In this research, we want to understand whether the visualization software has an impact on human understanding of the information exchange process in large-scale health informatics communities.

2 Related Work

This section of the paper explores the related work in the area. In particular, we are interested in the application of Visualization to the field of health informatics when it comes

to the transmittal of electronic health record information inside of Health Information Exchanges.

As mentioned in the introduction, Visualization provides a way to understand complex interactions and relationships in real world data. Hence, it is not surprising that Visualization can be employed in applications and environments relating to health informatics.

For example, Hansen et al. developed a system to track how hospital workers moved throughout the hospital in order to track the spread of infections within a hospital environment. The interface for this system employed large data sets as well as an interactive touch screen in order to understand how infection control experts might use such a system to prevent outbreaks of infectious diseases [3].

It is not uncommon for visualization can be combined with data mining techniques. For example, Lavrac et al. use data mining techniques in conjunction with visualization to identify areas in Slovenia that were atypical for availability and accessibility of public health services [6]. Furthermore, visualizations in the public health domain can also be used for resource planning [11] or to integrate diverse epidemiological data with the occurrence of certain types of cancers [12].

Visualization can also be employed from the viewpoint of the physician as discussed in several papers [1, 7, 14]. For example, Mane and Borner look at innovative ways of viewing medical data for the purposes of diagnosis [7]. Roque et al. discusses six visualization systems that mostly target the physician as a primary user [14]. The systems in Roque also make use of a timeline that allows the physician to correlate the events in the patient's history using the electronic health record data.

Finally, patient centered perspectives are also possible such as the design in featured in Rajwan and Kim's article [13]. In this particular work, the authors develop a system design to support the sharing of information between patients and physicians that uses visualization to share complex information requiring a high volume of data.

Mohawk's Visualizer takes a middle ground between these approaches and the tools discussed in Howard et al. [4] in order to display the infrastructure of the software components and how they transmit electronic health record information to one another.

3 Experimental Environment & Design

In order to understand the impact of the Visualization software on human understanding of the interactions involved in Health Information Exchanges, we designed a survey instrument. The survey collected demographic information relating to the participant's organization, role within the organization, age range, and gender. In addition to the demographic questions, we posed six questions concerning the effectiveness of the Visualizer for displaying information about the Health Information Exchanges. These latter six questions were all constructed using a 5-point Likert scale (strongly agree to strongly disagree) and were worded as follows

- Using only an architectural diagram, it is easy to understand how Electronic Health Record information is transmitted between individual systems in a complex architecture
- Using the Visualizer from MARC-HI enables me to understand how Electronic Health Record information is transmitted between individual systems in a complex architecture
- The Visualizer from MARC-HI facilitates understanding of various vendor products within a complex architecture
- Interpreting standard audit messages and illustrating this information is important
- The Visualizer from MARC-HI facilitates the interpretation of standard audit messages
- The Visualizer from MARC-HI facilitates the illustration of audit information

We distributed the paper-based survey to 35 participants at the 2012 HIMSS Conference in Las Vegas, Nevada who took part in the IHE Interoperability Showcase event. Since surveys were only distributed to visitors to the visualization booth, the response rate was 100%. However, this distribution method introduced a limitation into the applicability of the results, since the participants were all health informatics professionals who had an interest in visualization. Hence, it is important not to extrapolate the survey findings beyond this audience.

4 Discussion & Results

This section of the paper contains the results from the survey. Accordingly, the first subsection presents the demographics of the survey population whilst the second subsection presents the results for the Likert-scaled constructs.

4.1.1 Participant Demographics

The survey design divided the participants into five different age ranges, specifically 18-30, 31-40, 41-50, 51-64, and 65+. As can be observed in Figure 2, the majority of participants fell into the 31-40, 41-50, and 51-64 categories. There were only 2 participants in the 18-30 age range, 2 who did not answer, and no participants over the age of 65. This distribution was not surprising given that the sample came from a population of individuals employed in professional careers.

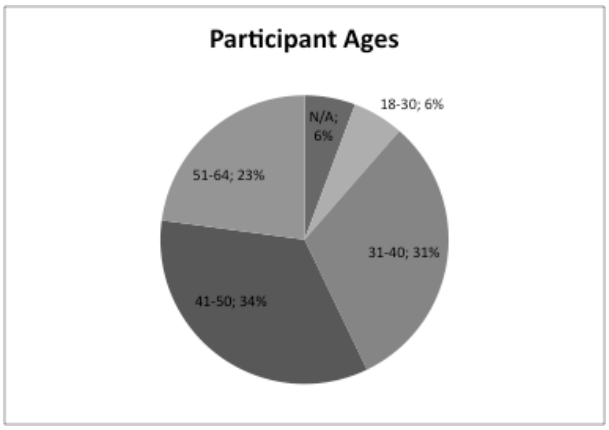

Figure 2: Participant Age Ranges

Likewise, the demographics for participant gender were skewed toward male participants as can be surmised from Figure 3. Given that the conference attracted a large number of computer and technical professionals, this finding is not surprising either.

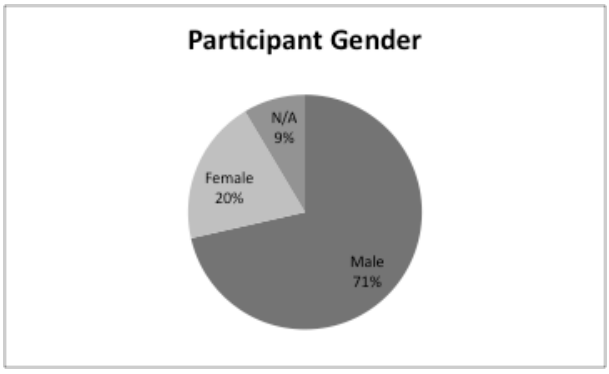

Figure 3: Participant Gender

The final piece of demographic information analyzed here is the participant role in their organization. Figure 4 shows that fully 2/3 of the survey participants were engaged in technical roles with their organization while another 31% worked in management and sales. Again, this finding reflects the general demographics of the HIMSS conference, which was designed to attract professionals in the field of health informatics.

In addition to the participant role, we collected free form reporting of the participant's organizational affiliation. The vast majority of technical participants worked for technical companies such as Oracle and Optum whilst most management and sales participants worked for healthcare institutions or for universities.

Figure 4: Participant Roles

4.1.2 Survey Question Results

This section discusses the results from the Likert-scaled questions. For the first question, we asked participants to rate their degree of agreement with the statement: *"Using only an architectural diagram, it is easy to understand how Electronic Health Record information is transmitted between individual systems in a complex architecture"*.

Figure 5 shows the distribution of the responses for this question. The mode for the responses was 4 whilst the mean was 3.9[1]. In general, participants were positively poised as to the effectiveness of this approach.

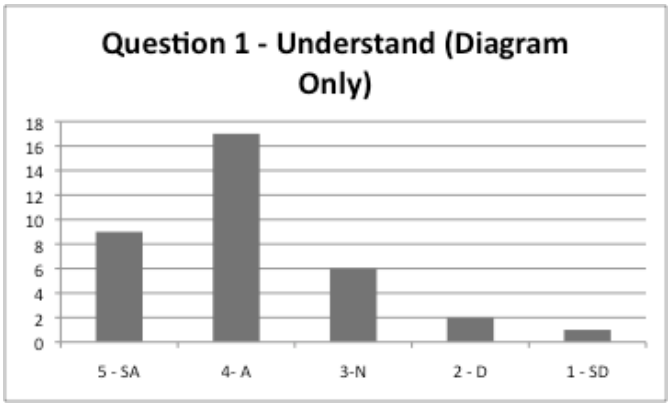

Figure 5: Understand Information Transmittal (Diagram Only)

Question 2 asked participants to rate their degree of agreement with the following statement: *"Using the Visualizer from MARC-HI enables me to understand how Electronic Health Record information is transmitted between individual systems in a complex architecture"*.

[1] Note: Likert-scale constructs are ordinal data, so we report the mean as a measure of central tendency for informational purposes only. All statistical tests we conduct are non-parametric and designed for ordinal data.

As can be seen in Figure 6, the participants were positively poised regarding the effectiveness of the Visualizer with the mode for responses being 5 and the mean being 4.7.

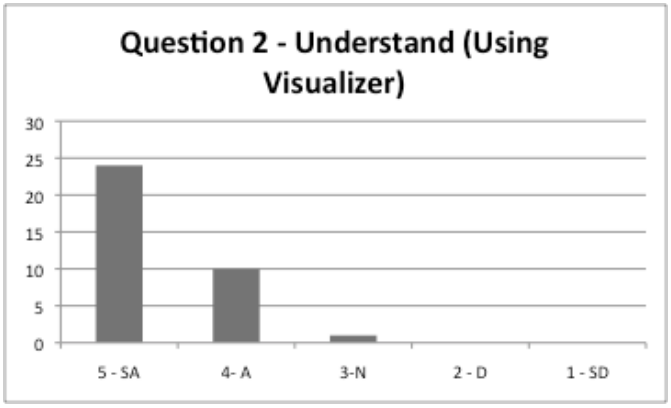

Figure 6: Understand Information Transmittal (Using Visualizer)

Question 3 asked participants to rate their degree of agreement with the statement: *"The Visualizer from MARC-HI facilitates understanding of various vendor products within a complex architecture"*. The results for this question are shown in Figure 7. Again, the mode for all responses was 5, and the vast majority of participants were positively poised about the Visualizer's ability in this regard.

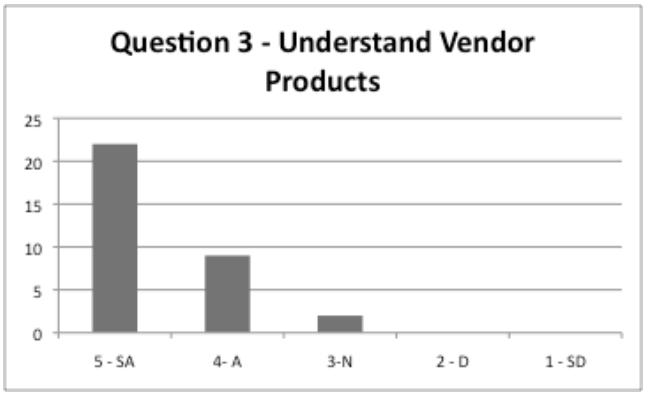

Figure 7: Understand Vendor Products

Question 4 asked participants whether interpreting standard audit messages and illustrating them was important. Again, the participants tended to agree with this statement. 19 reported that they strongly agreed with the statement, 11 agreed with the statement, and 3 remained neutral in this regard. The results for this question are shown in Figure 8.

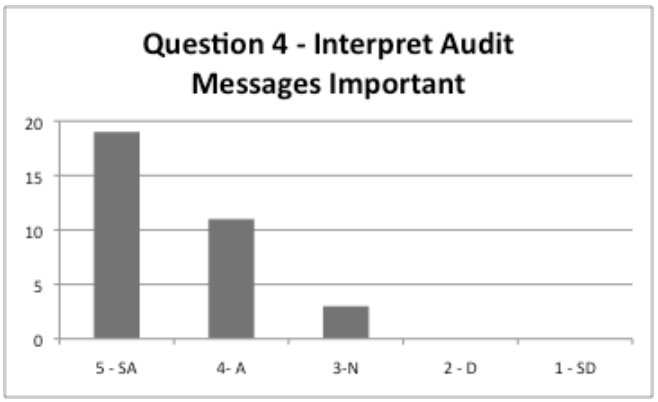

Figure 8: Interpreting Audit Messages is Important

Question 5 asked participants whether they agreed that the Visualizer facilitated the interpretation of standard audit messages. This question was more contentious than previous questions, since 2 participants disagreed and 3 left the construct blank. There were a higher number of neutral responses than the previous questions as can be observed from Figure 9.

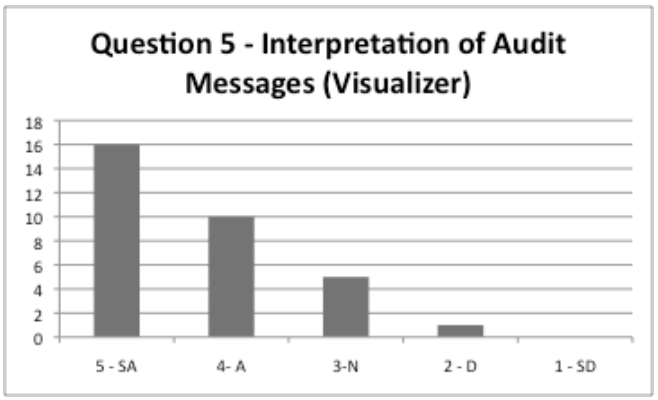

Figure 9: Visualizer Facilitates Interpreting Audit Messages

The final question in the survey asked subjects to rate their degree of agreement with the statement: *"The Visualizer from MARC-HI facilitates the illustration of audit information"*. Figure 10 displays the results from this question. Although there are no negative responses to this question and the respondents are generally positively poised about the subject, there were two blank responses on the survey sheets.

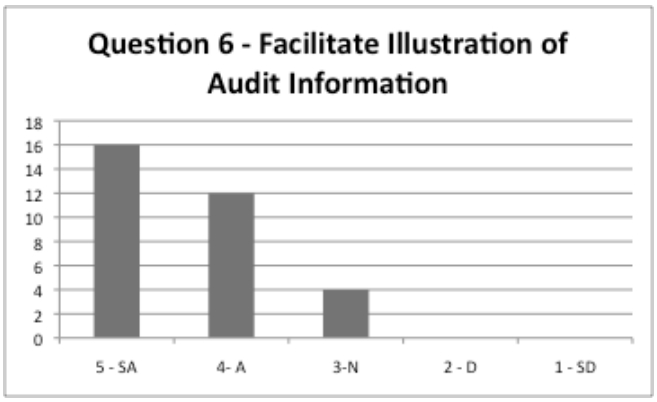

Figure 10: Visualizer Facilitates the Illustration of Audit Messages

In addition to measuring the central tendency for the six Likert-scaled questions, we also ran non-parametric tests such as the Mann-Whitney Wilcoxon and Mann-Whitney U-Test in order to discern whether there were significant differences between the distributions for the responses.

While there were no significant differences between any pair-wise matching of questions 2-6, there were significant differences between question 1 and the rest of the questions.

In particular, a Mann-Whitney Wilcoxon test between questions 1 and 2 generates a z-value of 3.8646 and a p-value of 0.0001. This indicates a highly statistically significant difference between questions 1 & 2. Furthermore, the more robust Mann-Whitney U-Test also yields a p-value of 0.0001. Hence, we can conclude that users have a significantly easier time understanding the exchange of electronic health record information in health information exchange communities with the aid of the Visualizer.

Likewise, the statistical differences between question 1 and the rest of the questions are indicative of the fact that the other questions (2-6) focus on the effectiveness of the Visualizer.

5 Conclusion

Visualization is greatly useful for understanding the complex interactions that take place in large-scale communities of interdependent systems, such as those found in Health Information Exchanges. Mohawk's Visualizer software uses audit repository messages from systems that process electronic health record data to display the flow of information between the systems.

This research developed a survey mechanism to evaluate the effectiveness of this approach on human understanding. The survey was administered to 35 health informatics professionals who attended the IHE Interoperability Showcase display at the HIMSS conference.

The survey found that participants were positively poised regarding the Visualizer's ability to facilitate understanding of vendor products in complex architectures, assist in interpreting audit messages, and facilitate the illustration of audit information. Most importantly, users reported a highly statistical difference in their understanding of the transmittal of electronic health record information when using the Visualizer software as opposed to an architectural diagram.

6 Future Work

A key limitation as to the applicability of this work on a larger scale is the fact that the survey population comes solely from business professionals who attended the interoperability showcase at HIMSS and stopped by the visualization booth. Hence, future work should focus on measuring the effectiveness of this tool and visualization for different populations.

In addition to surveying different user populations, several participants suggested the ability to drill down in the visualization in order to obtain additional information about the various components in each Health Information Exchange. These suggestions work well with the Visual Information Seeking Mantra, which states "Overview first, zoom and filter, then details on demand"[16].

Finally, extending the software to have statistical gathering capabilities can assist in user understanding of the entire process as evidenced by work such as Perer and Shneiderman [10].

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