Leveraging Information Visualization, Pattern Identification, and Anomaly Detection in Support of Tactical Analysis of Healthcare Contracts

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Abstract

Hospital operations are becoming more expensive due to increased demand, newer technology, and complex contract resource planning. This Study examines the effectiveness of information visualization technologies, particularly dashboards, in identifying trends and anomalies in service utilization. The project intends to empower hospital finance officials by addressing the difficulties associated with sophisticated ordering procedures and specialized demand forecasts. Through improving comprehension of the dynamics of service demand and aiding in the identification of anomalies, the suggested information visualization tool aims to support proactive and economical hospital administration. The information visualization tool was evaluated via the Communicability Evaluation Method, which showcased improvement in the performance of people with no prior experience in data analysis, resulting in positive feedback from participants in terms of perceived usefulness.

Additional Key Words and Phrases: Dashboard, Healthcare, Patterns, Performance Dashboard, Healthcare Dashboard, Pattern Recognition, Anomaly Detection

1 INTRODUCTION

Managing rising costs in hospital operations is difficult. Costs may rise due to multiple reasons, ranging from increasing demand for healthcare services [2], passing by the cost to acquire new medical technology, the cost of drugs and other supplies, and the efficient planning of resources in a contract. Planning resources in a contract is non-trivial because it is highly dependent on demand prediction in a highly specialized area and healthcare professionals, who are often not proficient in finance but in healthcare itself. For the same reason, it is also difficult to ensure the efficient use of resources planned in the contract.

Hospitals possess large amounts of both clinical and administrative data[2]. Provided the volume and its continuous expansion, hospital finance officers have been overwhelmed with the task of managing, keeping and using their own data[2, 3]. Recent works from the literature have shown the use of visualization tools and dashboards [1, 3, 14], for both managing and studying their data [2–4].

In this research, we investigate the use of information visualization tools to support hospital financial officers in analyzing data regarding the hospital's service usage. The proposed tool will focus on the free exploration of data, including aiding its users in pattern and anomaly recognition. The selected data analysis tasks can help hospital finance officers (1) understand the demand for services (and prepare for it adequately) and (2) identify mistakes in the ordering process. Detecting these anomalies is particularly relevant because ordering these services depends on highly specialized knowledge, usually done by expensive personnel and, therefore, difficult to audit by financial officers.

To investigate the aforementioned problem, a research plan was made and an overview of this plan is presented in Section 2. The first step taken was to conduct a review of the literature to answer the selected 'knowledge questions'. The literature review is discussed in Section 3. Related works, described in Section 3, were reviewed to identify the gaps in the literature and further organize the upcoming steps in this investigation.

A dashboard management tool was implemented according to the lessons learned from the literature and the 'knowledge questions'. The software features a wizard that was developed aiming at helping and teaching the user how to effectively perform data analysis. The tool is briefly presented in Section 4 to keep the focus on the mechanism developed (a wizard) to support hospital finance officers in data analysis, including the detection of patterns and anomalies.

To evaluate the impact of the visualization tool, an empirical evaluation was planned, consisting of a three-step approach as described in Section 5. In the first step, demographic information is collected to identify the participants existing knowledge within the field of data analysis. In the second step, participants are asked to complete a series of data analysis tasks, see Table 5 using the visualization tool. In the third step, participants are asked to provide retrospective feedback on their experience using the tool and completing the tasks.

Using the chart creation wizard (DSR artefact) 82.3% of participants succeeded in task 1 and 2, 70.5% in task 3, and 64% in task 4, 58% in task 5, and 41.6% in task6. The recording of 30% fail-rate was considered relevant, which indicated the need for further investigation of whether the mechanism is supportive enough, or whether there exists a variable that interferes with the results (level and field of education, and most importantly, data literacy level). However, qualitative remarks from users, pointed out how the tool had helped them learn about the topic and helped them succeed, despite the occurring communicability issues. Furthermore, the possibility to retain a positive outlook of up to 70% success rate on unknown data is something to consider. All of this went on to complete additional DSR cycles to improve the user interface and to better cluster the participants on the field of education and/or occupation, etc.

2 RESEARCH OVERVIEW

This section describes how the Design Science Research method[8], see Figure 5, was used to organize the current investigation regarding the design of an artefact to support hospital finance officers in analyzing data regarding hospitals' service usage. The main points

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discussed include the research problem, questions, and subquestions. Additionally, to systematically evaluate the designed artefact, specific methods were selected from the literature and applied in this investigation.

Problem statement: *The difficulty found by hospital finance officers in analyzing service usage data in search of patterns and anomalies.* The escalating costs associated with hospital contracts present a challenge in contemporary healthcare management. As healthcare expenditures continue to rise, financial officers struggle with the task of effectively managing financial demands, either by the lack of support for understanding the demand (and later on with demand prediction) or by the lack of support for inspecting service usage data.

Main Research question (RQ): *How can an information visualization tool be designed to support hospital finance officers in the analysis of service usage data?* This main research question translates the problem statement and clarifies the goal to support financial officers in their data exploration and analysis. We assume as a premise that this support can result in improvements in the planning for future demand and in the scrutiny of the service usage within contracts (based on past usage listed in their datasets).

To answer the main research question, in this research, we chose to design an artefact (an information visualization tool). According to the DSR [8], the artefact should be designed according to a specific Body of Knowledge (BoK) and environmental data. The BoK that informed this design is discussed in Section 3, which aims to answer the following knowledge questions:

- **KQ1**: Which information visualization tools and techniques could benefit hospital financial officers the most in identifying patterns and anomalies?
- **KQ2**: What are the usability evaluation tools & techniques recommended by literature to evaluate such an artefact (system)?

Following the guidelines from the literature review, a chart-creating wizard (the artefact around which we applied the design cycles of Design Science Methodology) was designed. This is the next in this research procedure and is described in detail in Section 4. An entire system was developed to support this investigation, which is centered on one specific interface mechanism that seeks to support hospital finance officers in analyzing their data: a chart creation wizard. Our hypothesis is that this mechanism will support the user in choosing the most appropriate visualization tool and, therefore, support them in the data analysis. The hypotheses statements are as follows:

Hypothesis: *The proposed interface mechanism (a wizard) is (a) easy to use and (b) supports hospital finance officers in the data analysis.* In order to evaluate this hypothesis, this research used the Communicability Evaluation Method (CEM) [13]. This method identifies problems in the user interface that affect its usability. If the usability is not good enough, the main hypothesis of this research must be refuted (part a). Additionally, to check whether the proposed interface mechanism (the wizard) supports the users in the data analysis, we performed a three-step analysis comprised a pre-task assessment, purposefully designed tasks, and a post-task assessment. The goal is to investigate whether users gained a better understanding of data analysis and, more importantly, of their data (part b). The pre-task assessment aims to determine demographic data and to assess the participant's proficiency in data analysis. The purposefully designed tasks aim to investigate whether the participant, given a certain data analysis task, makes an appropriate choice of the visualization tool. Additionally, the last task aims to investigate whether the user can find any pattern or anomalies in the data with the chosen visualization tool. The hypothesis must be refuted if the artefact usability is inadequate (part a) or the software does not adequately support the participant in learning about their data (part b). The usability is considered inadequate if the user is unable to learn and/or understand the underlying concepts behind each operation of the visualization tool. Furthermore, the support for data analysis is considered inadequate if users give up or produce results, that are perceived as correct, but are not. Furthermore, the CEM tags that would be most desirable to validate the desired outcome would be *thanks, but no*, *I can do otherwise.* On the contrary, the least desirable tags would be *I give up* and *Looks fine to me...*

Participants Selection: The participants for this empirical study should be selected in two blocks. First, students of the University of Twente will be invited to participate (voluntarily). The goal of inviting students is to diversify the participants' profiles. A Second group of participants will be provided by a manager at the hospital, consisting of potential users of the system being developed. The goal of the second group is to gain insight into the context in which the system will be used.

3 LITERATURE REVIEW

According to a literature review conducted by Eckerson *et al.* [6], hospital dashboards can be classified into three types, namely strategic, tactical, and operational with each type supporting a different level of management personnel [see Table 1]. By examining each distinctive dashboard type, we can derive the requirements for the proposed artefact. Furthermore, these requirements support the choice of visualizations that would be suitable to integrate into the tool for the first cycle of the DSR. A comparison between the dashboard types is listed in Table 1.

Types of Hospital Performance Dashboards		
Strategic	Tactical	Operational
Used by Top Level Management	Used by Departmental Managers	Used by Front-line clinics
Monitor the execution of strategic objectives	Monitor progress and emphasize analysis	Monitor the performance of core operational processes in real-time
Emphasise management more than monitoring and analysis	Enables users to investigate data across many dimensions	Enables visual summary of decision-related clinical information
Shared on any level of the organization,	Shared within managers of the department	Shared only between clinics

Table 1. Types of Hospital Performance Dashboards [3]

Strategic hospital dashboards aim to serve upper management, focusing on monitoring and execution of strategic objectives. These dashboards prioritize management above monitoring and analysis. Their use is widely adopted throughout organizational levels to guarantee compatibility with strategic objectives. This category of dashboards primarily serves to reinforce strategic decision-making processes at the executive level.

Tactical-level hospital dashboards are designed for departmental managers, providing the ability to track processes and explore data in multidimensional arrangements. This type of dashboard, allows managers to maintain focus on performance concerning operational and financial objectives, thus providing a basis for the investigation of underlying causes of highlighted circumstances. The capabilities of tactical dashboards allow managers to recognize patterns related to departmental processes accurately. Thus, tactical dashboards can serve as a backbone for informed decision-making at the departmental level.

Operational-level hospital dashboards, cater to front-line clinical users, delivering real-time monitoring of operational processes [6]. Front-line clinics include medical personnel working directly with patients. Focused on providing critical information, this type of dashboard empowers healthcare professionals to monitor performance in real time. By offering a simple-to-understand interface for monitoring key operational metrics, these dashboards contribute to enhanced decision-making.

Yigitbasioglu and Velcu [20] describe hospital performance dashboards as a graphical user interface that measures business performance to enable managerial decision-making. Hospital performance dashboards support decision-making by structuring the information, and highlighting factors while making data easier to evaluate and therefore helping users analyze information [4]. To provide appropriate information, given the amount of data to be presented, a dashboard's structure can be divided into 3 distinct layers, namely outer, middle and inner[6]. The three layers are compared in Table 2.

Layers		
Outer Layer	Middle Layer	Inner Layer
Represents graphical and metric data, which are often used to monitor performance	Consists of dimensional data,	Consists of the detailed data.
Often these are presented as graphs, charts and alerts.	Allows users to analyse data across many dimensions and organisational hierarchy,	Most data in this layer are delivered as reports or lists.
When performance exceeds a threshold, the dashboard alerts users	Allows the user to explore the mortality rate by department, whereas for hospital incidents the user can view by category	drill-down, where performance dashboards provide the ability to go from summary to detailed information

Table 2. Dashboards structure information in different layers. [3]

The outer layer of a dashboard represents the graphical and metric data representing the desired performance indicators. Furthermore, this layer is also responsible for alerting users when pre-defined thresholds are exceeded[3]. The middle layer of a dashboard focuses on multi-dimensional data, thus allowing its users to perform analysis across different dimensions and organizational hierarchies[3]. The inner layer of a dashboard contains the full sparsity of the gathered data, including any form of metadata relative to the recorded information. This layer focuses on enlarging the reach of observed data, therefore providing an analytic perspective of the data[3].

Dashboard adoption is expensive and demands significant manpower. [2, 3, 14]. Provided the large investment and scope, information visualization tools within the healthcare industry must also adhere to a set of requirements, enable easy utilization [1, 3, 14], improve situational awareness [1] and focus on providing the required information visualizations methods to a wide range of user-specific cases and healthcare domains. [1, 2, 4, 14, 16].

Buttigieg *et al* [3] emphasize the need for empirical studies focused on visualization tools within the healthcare sector. This is an emergent area with many open research questions. Empirical studies help understand the usage of dashboards in the healthcare context and contribute to the maturity of the research in the field.

Egan et al[7] within the healthcare sector focuses on clinical dashboards, emphasizing their role in integrating technical data within intensive care units. With the increase in information accuracy and availability, such tools greatly enhanced care quality and clinical outcomes, therefore expressing the importance of metrics and data visualization within the field.

Kaufhold et al.[9] explored the effects of visualization tools on Computer Emergency Response Teams (CERTs). This study addresses the complexity of monitoring and responding to cyber threats, proceeding with practical design implications for enhanced prevention and response mechanisms. Furthermore, the study highlights officers' increasing difficulty in interpreting and understanding data adequately, leading to reduced situational awareness and lower performance. This study concludes with a discussion on the positive influence of visualizations when dealing with large amounts of data.

In the education field, Park and Jo [10] analyzed the impact of the Learning Analytics Dashboard (LAD) on students' online behavior patterns. In their findings, the paper emphasized the role of visualized information in influencing students' understanding levels and satisfaction. Such a phenomenon described the positive feedback of applying visualization tools in support of information and data analysis.

According to Dowding *et al.*[5] and Pauwels *et al.*[11], "a clinical dashboard is designed to provide clinicians with the relevant and timely information they need to inform daily decisions that improve the quality of patient care. It enables easy access to multiple sources of data being captured locally, in a visual, concise, and usable format.". Thus, looking into data visualization techniques, Stoltzman[17, 18], Starren *et al.* [16], Vaezipour *et al.* [19] and Saary and M Joan [15], analyzed different charts and highlighted their potential when used in sectors dealing with large amount of data. The researched charts are categorized in Table 3

The table summarizes the reviewed charts categorized by their usage and focused group. Therefore, it is outlined that line chart [18], bar chart [18], bubble chart [19], heatmap [6] and treemap [18] are meant to be used by management officers. In comparison, polar

Studied Visualizations		
Type	Focus Group	Usage
Heat Map [6]	Management Staff	Magnitude of Values
Tree Map [18]	Management Staff	Magnitude and hierarchy of values
Line Chart [18]	Management Staff	Comparison of values
Bar Chart [18]	Management Staff	Composition of values
Bubble Chart [19]	Management Staff	Comparison of Values
Polar Chart [16]	Front-Line Staff	Magnitude of values
Radar Charts [15]	Management Staff	Multivariate Data

Table 3. Studied Visualizations

and radar charts[15, 16] cater to front-line professionals. The summarized overview of those visualizations showcases their benefits for each focus group, thus providing useful insight to two of the focus groups within the healthcare sector.

One of the primary findings highlighted by this literature review is the beneficial role of dashboards in conveying information, thereby enhancing the overall quality and provision of patient care[7]. Additionally, Buttigieg *et al* [3] highlighted the need for empirical evaluations of visualization tools in medical environments. Furthermore, as explored by Park and Jo[10] and Kaufhold et. al. [9] the introduction of information visualization tools in such environments could have a substantial influence on understanding the underlying data.

4 ARTEFACT DESIGN

In the first design cycle of this research, the developed artefact is a step toward a dashboard. Provided the lack of empirical studies in the healthcare sector[3], it's important to investigate each step in the development to ensure adequate support in the context of its use. That said, in the first cycle we focused on the basic features (like loading datasets, combining them, etc.) with a specific interface mechanism designed to support users in choosing the proper visualization tool for the subsequent data analysis. The interface mechanism is a wizard, illustrated in Figure 1

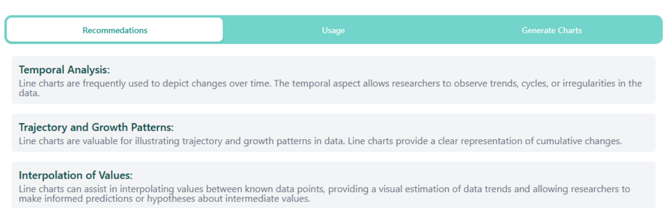

Fig. 1. Outer Layer (part of): Wizard Chart Instructions

The wizard was designed to support the selection of the most appropriate visualization tool for the data analysis task at hand. Once the user selects a visualization, the user is presented with the situation in which the selected visualization is recommended. Additionally, the Usage tab presents instructions for the generation of the chosen visualization.

The current dashboard prototype is of a tactical level aiming to support hospital financial officers in performing data analysis. Regarding the layers, the inner layer provides a direct overview of the gathered data, as illustrated in Figure 2;

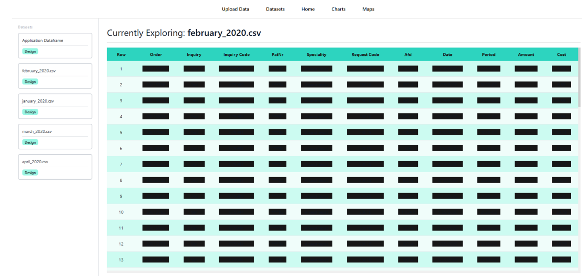

Fig. 2. Inner Layer: Dataset Overview

The visualization tool supports the ability to look into the raw data. This allows for low-level investigation of the data and its format. The middle layer supports the connection between multiple datasets, as presented in Figure 3;

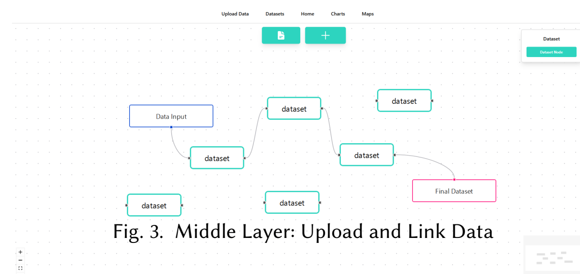

Fig. 3. Middle Layer: Upload and Link Data

The artefact provides the ability to connect datasets. Such connections allow data analysis using differing data formats.

Finally, the outer layer of this tool consists of 5 charts and 2 maps as described in Table 3.

(a) (b) (c)

Fig. 4. (a) Heatmap Map (b) Bar Chart (c) Treemap Map

The purpose of this layer is to represent the data in a visual format. It supports multiple visualization tools, shown in Figure 4, focusing on the comparison and composition of values through different approaches of data visualization.

5 EMPIRICAL EVALUATION

As explained in Section 2, the empirical evaluation consisted of a three-step approach. In the pre-task assessment, the following demographic information was collected: year of birth (age), occupation, and prior experience with data analysis and dashboard tools, see Table 4.

Demographics		
Label	Type	Description
What is your year of birth?	Temporal,	Used for capturing user bias
What would be the highest finished level of education you have reached?	Textual	Used for capturing user knowledge
What is your current occupation?	Textual	Used for capturing user experience

Table 4. Participant Demographic Information.

Demographic data of participants was collected to determine an initial baseline. This baseline would be used at the end of the experiment to explore the impact of the artefact on the user.

The second step in this evaluation consisted of two parts: communicability evaluation with the use of the method CEM [12, 13], and task performance analysis. The evaluation with CEM aimed to assess the tool's usability (hypothesis part a), while the task performance analysis combined with the demographic data aimed to assess the software support in data analysis (hypothesis part b), including finding patterns and anomalies.

Tasks	
Task	Description
Given the dataset "january 2020" containing laboratory analyses collected in January 2020, choose a suitable visualization to compare the total count of requests per specialization (specialty).	(a) Use the Line chart and select the column "Speciality"; (b) Use the Bar chart and select the column "Speciality"
Explore the "february 2020" dataset, focusing on total spending per specialization. Your task is to select an appropriate visualization that you believe would best visually represent the monthly expenditure on laboratory analyses across various specialties. Compare and highlight spending patterns.	(a) Use the Line chart and select the column "Speciality" and function "item"; (b) Use the Bar chart and select the column "Speciality" and function "item"
Now proceed to analyze the "april 2020", provided the given types of visualization methods at hand, find columns/values that highly correlate to each other and name them out loud	(a) Use a Heatmap and find 2 correlating variables; (b) Use a Radar chart and find 2 correlating variables;
Provided your findings in the previous sub-question, proceed to investigate whether you can find a relation of the magnitudes between those columns. If you have not identified any relation in the previous sub-question, use the fields that make sense to you the most	(a) Use a Bubble chart and input the previous 2 correlating variables; (b) Use a Polar chart and input the previous 2 correlating variables;
Proceed with analyzing the dataset "january 2020". Within the dataset investigate the quantitative proportions of at least 3 columns. Quantitative proportions indicate subsections of a larger group relative to other larger groups.	(a) Use a Treemap and find the 3 largest columns; (b) Use a Treemap and find the 3 largest columns
Having looked into the quantitative distribution of data within the dataset, proceed with examining the data concentration within the dataset.	(a) Use a Treemap and a Heatmap; (b) Use a Treemap and a Bubble chart;

Table 5. Tasks

In the first task, see Table 5, participants engaged in a categorical analysis. The objective was to select a suitable visualization for comparing the total count of requests per specialization, see Table 13 for full analysis.

Given this objective, the CEM Tags to highlight include:, *I can do otherwise*, *I can't do it this way*, *What now?*, *What happened!*, *Looks fine to me...*. Examining the occurrence of the selected tags provided an overview of first impressions of the artefact and its ability to assist new users. While most did not experience struggles with accomplishing the task, the identification of tags *What now?* and *What's this?* as the most common tags, see Table 13, showed that participants initially struggled to understand how to accomplish the proceeding steps in choosing the correct visualization. In total 35.2% of participants were identified with tag *What now?*, and 41% were identified with tag *What is this?*. Summarizing the highlights of the task, see Table 6, Participants 8 and 9 experienced the most amount of difficulty, including P9 being unsuccessful in its completion. Participants 7 and 10 not only completed the task successfully but also identified more than one possible visualization. Besides slight initial confusion, participants 11 and 14 were successful in completing their tasks, while showing no further uncertainty. The total completion rate of this task was 82.3% across all users.

CEM Task One Highlights						
Tag	P7	P8	P9	P10	P11	P14
Looks Fine to me...			X			
What Now?		X	X		X	X
What's this?		X	X			
I can do otherwise	X			X		
What Happened?	X					

Table 6. CEM Task One; Sub-part of Figure 13

In the second task, seen in Table 5, participants were instructed to focus on total spending per specialization, necessitating the selection of an appropriate visualization for the visual representation of monthly expenditure.

CEM Task Two Highlights						
Tag	P3	P8	P9	P11	P14	P15
Where is it?		X	X	X		
I can't do it this way				X		
What Now?		X	X		X	
What's this?	X	X	X	X	X	X
oops..					X	X

Table 7. CEM Task Two; Sub-part of Table 14

Provided the objective, the CEM tags to focus on are as follows: *Where is it?*, *I can't do it this way*, *What now?*, *What's this?*, *oops...*, as seen in Table 7. The persistent occurrence of *What Now?*, exhibited by 52.9% of participants, and *What's this?* found present among 58.8% of test subjects, demonstrated an inability to task comprehension. These results confirmed that the highlighted participants had little to no prior experience in data analysis. This is further emphasized by the performance of Participants 3 and 15 who accomplished the desired result without the detection of more than 2 focus tags. The *Where is it?* tag was present for both participants 8 and 9, indicating difficulties in locating specific task elements. *I can't do it this way* was denoted once for Participant 11 when selecting an inappropriate visualization. Nonetheless, all participants, except P9, were successful in completing their tasks. Looking into performance across all participants, we could see that the participant's ability to learn and select the correct instrument for the task has increased compared to task one, as seen in by tags *thanks. but no* and *I can do otherwise* in Table 14. Overall subject performance of task two resulted in 82.3% success-rate

The third task, see Table 5 required participants to conduct a correlation analysis, seeking columns or values with notable correlation.

CEM Task Three Highlights						
Tag	P2	P3	P4	P11	P12	P14
Why doesn't it			X	X	X	
I can't do it this way				X	X	
Where is it?	X		X	X		
What's this?		X		X	X	X
I can do otherwise		X	X			

Table 8. CEM Task Three; Sub-part of Table 15

The CEM tags that best accompany this tasks include: *Why doesn't it*, *I can't do it this way*, *Where is it*, and *I can do otherwise*, These tags described the comprehension of users when required to generate unfamiliar and/or uncommon to the participant visualizations. Looking into the highlights of the evaluation, as showcased in Table 8, the common presence of tags *What is this?* (58.8%) and *What now?* (52.9%) indicated that for a large partition of participants, the task and appropriate visualization were unfamiliar. Analyzing overall participant performance resulted in mixed results. While some participants were successful in completing the task, in addition to discovering multiple possible visualizations, others experienced increased difficulty in conceptualizing its completion. These findings were further emphasized by a large number of occurrences of the CEM tags *Why doesn't it* and *oops..* as seen in Table 15. Task performance dropped to 70.5% percent, compared across all participants.

In the fourth task, see Table 5, participants were asked to investigate the magnitudes between columns identified in the preceding sub-question, or in the absence of identified relations, focused on fields considered most relevant.

CEM Task Four Highlights						
Tag	P1	P3	P7	P10	P12	P14
Help!	X		X	X	X	
Why doesn't it?		X	X		X	
What Now?	X			X	X	
What's this?	X	X	X	X	X	X
oops..				X	X	X
thanks, but no				X		
I can do otherwise			X	X		

Table 9. CEM Task Four; Sub-part of Table 16

Given the objective of the task, the CEM Tags to highlight consisted of the following: *Help!*, *Why doesn't it!.*, *What now?*, *What's this?*, *oops...*, *Thanks,but no*, *I can do otherwise*. These tags outlined the degree of understanding of the participant when choosing the correct visualization given the task at hand, see Table 9. A high count of tags *What's this?* (41.1%) and *Help!* (35.2%), showcased that participants struggled significantly. Enriched presence of tags *What now?* (52.9%), *Looks fine to me* (17.6%), and *I give up*, as seen in Table 16, showed that participants were unable to select the correct tool for visualization. While the occurrence of tags *I can do otherwise* (29.4%) and *thanks, but no* (11.7%)remained similar to the outcome of the previous task, participants performed worse overall, including some giving up on finishing the task. This notion was reflected in the completion rate of the task, which enumerated close to two-thirds (64%), compared to participant performance in task three.

CEM Task Five Highlights						
Tag	P1	P2	P4	P7	P11	P16
Help!			X	X		
I can't do it this way				X		
What Now?		X	X		X	
What's this?	X					X
oops...			X			X
thanks, but no	X					
I can do otherwise	X			X	X	

Table 10. CEM Task Five; Sub-part of Table 17

The fifth task, see Table 5 involved exploring the quantitative proportions of at least three columns.

Provided the objective, the CEM tags to focus on are as follows: *Help?*, *I can't do it this way*, *What now?*, *What's this?*, *oops...*, *I can do otherwise* as seen in Table 7. This showcased mixed results. While participants 2, 4, and 16 struggled to accomplish the task, participants 1,7, and 11 managed to explore possible visualizations and find more than 2 correct forms of data visualization. These mixed results are further emphasized by the performance evaluated across all participants, as seen in Table 17. The increased count of tags *I can do otherwise* (41.1%) and *thanks, but no* (17.6%) showcased that although participants were unfamiliar with the procedure, 58% successfully completed it whilst selecting multiple viable visualizations. However, the overall CEM tag count increased in comparison to task four. This indicated that participants were not able to easily select and recognize the correct visualization for the task.

In the sixth task, see Table 5, participants were asked to conduct a magnitude analysis looking into data concentration within a dataset.

CEM Task Six Highlights						
Tag	P3	P8	P9	P11	P14	P15
Where is it?	X	X	X	X		
I can't do it this way	X			X		
What Now?	X	X	X		X	
What's this?	X	X	X	X	X	X
oops..	X		X	X	X	X

Table 11. CEM Task Six; Sub-part of Table 18

Requiring the participants to perform a task similar in concept but significantly harder, the CEM tags to focus include: *where is it?*, *I can't do it this way*, *What now?*, *what's this*, and *oops...*. As observed in Tables 18 and 11, participant performance plummeted. Participants 3, 11, and 14 experienced the largest shift in performance. Compared to their previous performances, the last task resulted in more than twice the count of occurrences, as seen in Table 11. Furthermore, performance across all tags, besides *Looks fine to me* and *Why doesn't it* and all participants plummeted. Provided the goal of the task, and its similarity to task three in terms of execution, the root of this phenomenon could be the difficulty of the task itself. Due to such difficulty spiking, 7 of 17 participants were able to complete the task.

Finally, the third step consisted of collecting retrospective feedback and additional data to support the investigation of the software's influence on the task performance.

The feedback garnered from study participants reveals nuanced perspectives on the efficacy and usability of the developed tool. Overall, a positive sentiment was discerned, with users expressing favorable impressions regarding the tool's utility and informativeness. However, the analysis identified noteworthy challenges, primarily associated with language comprehension and the tool's intuitive characteristics.

Participants highlighted difficulties arising from the absence of specific English terms in the posed questions, impacting the tool's operational feasibility. Subsequently, certain functions were identified as somewhat unintuitive, leading to challenges in comprehending outcomes. Accessibility and initial setup were denoted as notable issues for a subset of participants, with participants experiencing difficulty in locating and configuring the tool.

6 RESULTS

Participant performance results showcased significant differences between one another. Some experienced little to no difficulty, while others expressed a degree of uncertainty during task execution. Notably, participants with little to no prior experience produced results, similar to those having prior knowledge of data analysis. However as the difficulty of the task increased, all participants struggled to choose appropriate visualizations. Despite these results, the majority of participants completed their tasks successfully. Moreover with each subsequent task success rate remaining uniform, an increase of positive CEM Tags (*I can do otherwise* and *Thanks, but no*) was found.

Retrospective feedback from participants yielded largely positive results with 7 out of 10 participants having expressed words of positivity, highlighting that the tool had helped them accomplish the tasks, as well as learn about new forms of visualizations. 3 out of 10 participants stated that the usage of the tool seemed unintuitive and that it could have been useful in the hands of more experienced people.

7 CONCLUSION AND FUTURE WORKS

The empirical study showed the potential of the tool but also highlighted room for improvement that will be addressed in future work. Additional design cycles and empirical studies would need to be conducted. Furthermore, additional experiments within hospital environment would be made to better understand their needs in terms of data analysis. After capturing participant performance and analyzing it using the Communicability Evaluation Method, mixed results were found. While some participants benefited from the use of the tool and guidance of the wizard, others experienced significant difficulties whilst using it. Overall task completion, however, was not affected in any major or unexpected way. Nonuniform results were also depicted within post-procedure participant feedback. A large majority of participants denoted positive experiences while using the tool and wizard, stating that it had helped them learn new visualization techniques or increased their knowledge within the field of data analysis. Provided the experienced positive influence of the wizard on the participants and overall task performance, it was highlighted that integration of wizards within hospital information visualization tools, could positively impact the user experience of its users, thus increasing the performance of hospital officers in performing data analysis.

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A DESIGN SCIENCE RESEARCH CYCLE

The following section showcases the methods used for the production of the custom artefact used for the empirical study listed in this paper.

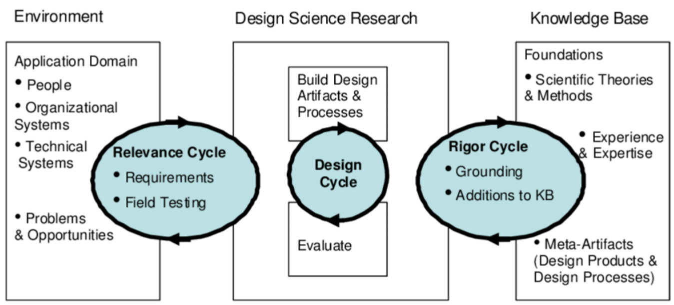

Fig. 5. Design Science Research Cycle

B PARTICIPANT RETROSPECTIVE FEEDBACK

User Feedback	
Participant Number	Feedback
Participant 2	Very impressed with the developed tool. My main concern is for myself the lack of some english terms in the questions, which made it to difficult for me at some points. But as i say, impressed!
Participant 4	the language is difficult; both for tasks to understand and afterwards doing it
Participant 5	For a person with no prior experience I found it really helpful. I wish I had some more time to "play with it" and make my skills even better.
Participant 7	Hard to find and set up initially, once displayed in graph really useful.
Participant 8	The platform might have been very helpful, however i did not read all of the instructions and it is not intuitive enough to use without reading the instructions
Participant 9	I like the platform the work with it
Participant 10	Its really informative and shows the graphs in well manner.
Participant 11	I believe the tool would have been useful in the hands of someone who had a better idea of what was going on; in my hands, it was a show of disaster that I don't blame the tool for.
Participant 14	The website looks really good. Its really informative and shows the graphs in well manner. I had no issues using the website.
Participant 17	Overall great software and the provided help was good

Table 12. User Feedback

C CEM TASK EVALUATION

Task One																	
Participant Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Looks fine to me									X								
I give up								X	X								
What happened			X														
Help!	X					X			X	X		X					
Why doesn’t it																	
Where is it?								X	X		X			X			
I can/t do it this way							X			X							
Where am I?							X	X	X								
What now?						X		X	X		X	X		X			
What’s this?	X		X					X	X						X	X	X
oops...														X	X		
thanks, but no	X																
I can do otherwise							X			X			X				

Table 13. CEM Evaluation: Task 1

Task Two																	
Participant Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Looks fine to me									X								
I give up								X	X								
What happened	X		X														
Help!	X						X				X						
Why doesn’t it			X														
Where is it?						X		X	X		X			X	X		X
I can/t do it this way							X			X	X						
Where am I?	X						X	X	X							X	
What now?	X	X				X		X	X		X	X		X			X
What’s this?	X		X		X			X	X		X			X	X	X	X
oops...			X											X	X		
thanks, but no	X									X							
I can do otherwise	X			x			X			X			X				

Table 14. CEM Evaluation: Task 2

Task Three																	
Participant Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Looks fine to me		X	X						X							X	
I give up								X	X								
What happened	X		X		X			X		X				X			X
Help!	X			X		X			X	X		X				X	
Why doesn’t it	X			X		X	X		X			X		X			
Where is it?		X		X				X	X		X						X
I can/t do it this way					X		X			X	X				X		
Where am I?	X						X	X	X				X				X
What now?			X		X	X		X	X		X	X		X		X	
What’s this?	X		X					X	X		X	X	X	X	X	X	
oops...			X		X			X			X			X	X		X
thanks, but no		X														X	
I can do otherwise			X	X			X			X			X			X	

Table 15. CEM Evaluation: Task 3

Task Four																	
Participant Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Looks fine to me		X		X					X								
I give up			X					X	X						X		
What happened			X			X	X	X					X				
Help!	X					X			X	X		X				X	
Why doesn’t it			X	X	X						X	X				X	X
Where is it?		X				X	X	X	X		X			X		X	
I can/t do it this way			X				X			X					X		
Where am I?	X				X		X	X	X			X		X			
What now?	X			X		X	X	X	X		X	X		X			
What’s this?	X		X			X		X	X			X		X			
oops...		X	X			X		X		X					X		
thanks, but no										X						X	
I can do otherwise							X			X			X	X		X	

Table 16. CEM Evaluation: Task 4

Task Five																	
Participant Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Looks fine to me	X	X						X	X								
I give up								X				X					
What happened			X		X		X			X			X	X			
Help!	X			X	X		X		X	X		X		X	X		
Why doesn’t it	X			X	X	X	X					X					
Where is it?				X				X	X		X			X			
I can/t do it this way			X		X		X			X							
Where am I?	X						X	X	X							X	X
What now?		X		X		X		X	X		X	X		X			
What’s this?	X		X		X			X	X					X	X	X	X
oops...			X			X	X			X				X	X		
thanks, but no	X		X										X				
I can do otherwise	X						X			X	X	X	X			X	

Table 17. CEM Evaluation: Task 5

Task Six																	
Participant Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17
Looks fine to me	X	X							X								
I give up	X							X	X								
What happened	X		X				X		X	X		X	X				
Help!	X		X		X	X			X	X		X	X				
Why doesn’t it			X	X	X												
Where is it?			X				X	X	X		X			X	X		
I can/t do it this way			X				X			X	X			X			
Where am I?				X			X	X	X				X			X	
What now?	X		X			X		X	X		X	X	X	X		X	X
What’s this?	X		X		X	X	X	X	X			X		X	X	X	X
oops...		X	X	X	X		X		X		X			X	X		
thanks, but no										X							
I can do otherwise				X			X						X				

Table 18. CEM Evaluation: Task 6