Evaluating Interactive Visualizations for Supporting Navigation and Exploration in Enterprise Systems

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Abstract: Enterprise Resource Planning (ERP) systems pose usability challenges to all but the most sophisticated of users. One such challenge arises from complex menu structures that hinder, rather than aid, system navigation. Another issue is the lack of support for discovering and exploring relationships between the data elements that underlie all transactions and processes performed with the system. Two dynamic, interactive visualizations, the Dynamic Task Map and the Association Map, were designed to assist users in ERP system navigation and data exploration activities. In this paper, we describe a laboratory study comparing the use of these visual components to standard SAP interfaces. Results from an initial empirical evaluation revealed that all users were able to complete tasks more quickly and with the same or a lower number of errors when using the visual components than when using SAP. Answers to questions comparing the standard SAP interface with visualizations also revealed an overall preference for the visual interfaces. Suggestions for improvements to the visualizations from study participants provided valuable feedback for future development.

1 INTRODUCTION

In the first issue of Interactions, Myers (1994, p. 74) wrote that "Time is valuable, people do not want to read manuals, and they want to spend their time accomplishing their goals, not learning how to operate a computer-based system." Over 20 years later, many Enterprise Research Planning (ERP) systems still stand between the users and their ability to achieve their work-related goals. Companies have learned the hard way that spending enormous amounts of time and money on ERP system training is a critical prerequisite for success. A case in point is the well-known ERP failure at Lumber Liquidators, which was blamed in large part on insufficient attention to user training (Krigsman, 2010).

Even with considerable investments in training, however, there are no guarantees that implementing an ERP system will be successful and will lead to increased productivity. Experience has shown that poor usability characteristics are at least partly to blame. Massive menu structures, inadequate navigational guidance, limited task support, and complex interfaces are just some of the obstacles facing users of these systems (Topi, 2005; Rettig,

2007; Scholtz et al,, 2010; Parks, 2012; Lambeck et al., 2014a, 2014b).

The motivation for this research comes from the belief that it shouldn't require such vast resources on the part of the company or herculean efforts on the part of its employees for ERP usage to meet with success. Today's workers have become more demanding of their office software after having experienced user-friendly personal devices, and ERP software providers are paying increased attention to usability (King, 2012). A recent Gartner report (Ganly and Montgomery, 2015) notes that ERP vendors are looking to improve the user experience by applying social software approaches to building communication tools. This tactic, however, won't tackle the systemic causes of poor usability.

Interactive information visualizations, on the other hand, can directly impact the user experience by providing tools and techniques for, among other things, selecting, filtering, exploring, and connecting data items (Yi et al., 2007). While such techniques are widely used by the visual analytics community (Pike et al., 2009), interactive visualizations are not prevalent in ERP systems.

In this paper, we present an empirical study of two interactive visualizations designed to aid ERP

system users in navigation and data exploration tasks (Babaian et al., 2015). The Dynamic Task Map (DTM) helps users locate the desired functionality by providing dynamic, interactive visualizations of transactions performed with the system. It reveals common usage patterns by visualizing measures that reflect aggregate user activity, such as the frequency with which a task has been performed. The Association Map (AM) highlights associative relationships between master data entities selected by the user. It presents an easy to understand, aggregated view of data relationships that would otherwise need to be extracted from detailed reports.

Ten study participants, all of whom were novice users of SAP, performed a set of tasks with each of these components and answered questions related to those tasks. They performed those same tasks and answered the same questions using the corresponding interfaces in SAP, a market leader in enterprise application software (Drobik, 2015). The installation used was SAP ECC 6.0 with SAPGUI 7.40 for Windows. The participants also answered questions comparing their experiences with each of the visual interfaces to those with SAPGUI. All of the participants took less time and answered at least as many, and typically more, questions correctly with the visual interfaces than with SAPGUI. The vast majority also preferred the visual components.

In the next section of this paper, we review related work. This is followed by a description of the visualization components under investigation. The user study setup is detailed and results from that study are then presented and discussed. We conclude with a summary of findings and directions for future work.

2   RELATED WORK

ERP usability issues have been documented in industry reports and articles as well as research studies (see, for example, Babaian et al., 2010; Cooprider et al., 2010; Lucas and Babaian, 2012; Scholtz et al., 2010). It has been readily acknowledged that these systems are typically difficult to use, particularly for novice users, and have very long learning curves. A study by Topi et al. (2005) defined six categories of usability problems, including the identification of and access to the correct functionality, system output limitations, and overall system complexity. More recent studies confirm that the issues identified in this work still persist today (Parks, 2012; Lambeck et al, 2014a; Lambeck et al., 2014b).

Rather than tackle ERP usability issues directly, however, research has often focused on the "human factor." Hurtienne et al. (2009) describes three ways for optimizing the fit between the user, the task, and the software. The first is adapting the business processes to the software (i.e., organizational change management). The second is user training, and the third is changing and adapting the software to the users and their tasks via customization. They note that while the first two approaches are critical for success, the third approach of customization is usually discouraged. Given that customization can be costly, time-intensive, and will typically need to be re-implemented in new releases, this is not surprising.

Having usability designed into the ERP system in the first place would be a far more preferable option. Integrating information visualizations into ERP interfaces is one way to work toward achieving this outcome. Parush et al. (2007) found that graphical visualizations improved performance of ERP users on tasks of varying complexity in two different task domains: Purchasing and Production planning and control. Visualizations can better represent quantitative data, integrate data from multiple sources, and aid decision-making. More advanced visual-spatial displays can support multi-source integration, which is essential for ERP performance, and can improve user fit, which contributes to ERP success (Hong and Kim, 2002).

A survey of 184 users of different experience levels using a variety of ERP systems revealed that being able to find the desired enterprise functionality is still a problem across all user experience levels (Lambeck et al., 2014a). They also found that the availability of useful and numerous visualizations can reduce user ratings of system complexity. Supplementary systems were found to provide more useful visualizations than ERP systems (Lambeck et al., 2014b).

Hipp et al. (2012) point out that being able to quickly and easily find process information during process execution is critical, yet most business processes are presented in a static way. Hipp et al. (2014) present a navigation space for navigating over large process model collections and related process information. They have applied this approach to complex, real-world automotive process models in an application called Compass. A controlled user experiment validated the usefulness of their three-dimensional approach, which consists of semantic, geographic, and view dimensions, for navigating complex process model collections.

While visualizations are being applied to tools and techniques for process navigation, discovery, and mining (van der Aalst, 2011), they have yet to be integrated in any significant way into ERP systems. In the following pages, we present and evaluate visual components that take us a step closer to the goal of improving ERP usability via dynamic, interactive visualizations.

3 ARTIFACTS

The two dynamic, interactive visualizations used in the study described in this paper were the Dynamic Task Map (DTM) and the Association Map (AM). The DTM was developed to assist users in ERP system navigation, while the AM supports data exploration activities. Both were implemented in D3 (see http://d3js.org). Earlier versions of these components were presented in Babaian et al., 2015.

3.1 Dynamic Task Map (DTM)

SAP, like other commercial ERP systems, includes a central menu structure called the SAP Easy Access Menu (see Figure 1), which is displayed on the system's front page. Despite its name, this menu is so massive and unwieldy that most users tend to avoid it, preferring to navigate the system by memorizing transaction codes and entering them directly. The only way to locate a transaction directly within the SAP Easy Access Menu is by expanding the menu branches and browsing the expanded view. SAP has two separate search functions for finding a transaction's code and location within the SAP Easy Access Menu. These functions, however, are not integrated with the menu.

Within each transaction screen, there is a separate menu with related tasks, located on top of the transaction screen. All aforementioned menus are fixed, in that they do not change with the use of the system. SAP also provides a Favorites menu, which can be configured by the users.

The Dynamic Task Map (DTM) provides an alternative means for finding a transaction via a dynamic, interactive visualization of transactions and the links between them. These transactions and links, along with their associated properties, are derived from ERP systems logs.

Each task in the DTM is depicted by a circular, blue node labelled with the task name, as shown in

Figure 2. The size of each node reflects the frequency with which that transaction has been performed. In the top left corner of DTM is a search interface, which locates transactions by name or by code. The visualization of all transactions does not display any links, as the resulting view would be too cluttered to be useful. Selecting a particular transaction, however, will cause the display to zoom in and make visible the links between that task and all transactions that typically co-occur or follow it, as shown in Figure 3. These connections are computed dynamically from SAP's internal usage logs, thus representing the actual way people use the system.
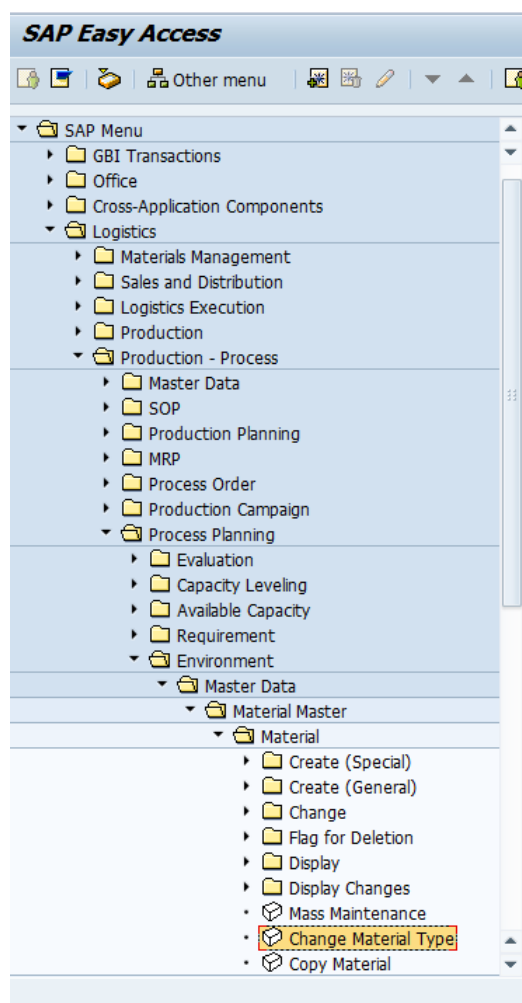

Figure 1: SAP Easy Access Menu expanded to locate the Change Material Type transaction.
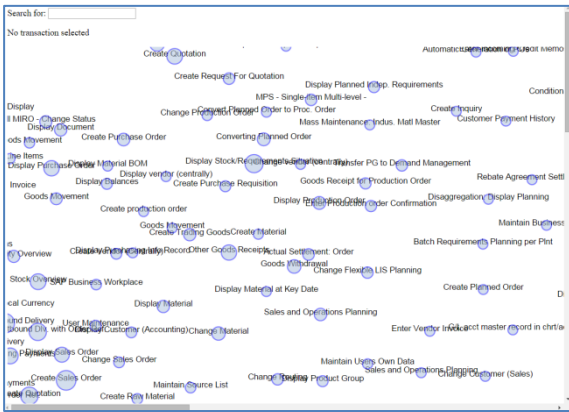
Figure 2: DTM visualization of all transactions. No nodes are selected. The search box appears in the top left corner.

To select a transaction in DTM, the user can either click on the node representing it or type its name (partial or complete) or transaction code into a search box. Figure 3 shows what is displayed after the user has selected the "Change Material" transaction. As can be seen, the selected node appears in yellow and bears a larger label. The name and transaction code for that node appear at the top of the visualization. Transaction codes can also be displayed by hovering the mouse over a node. Connected transactions are highlighted in red, with the intensity of the color reflecting the likelihood of that transaction following the selected one.

3.2 Association Map (AM)

Discovering relationships between master data elements in ERP systems can be a challenging process involving multiple steps. For novice users, even knowing where to begin can be problematic. Once the correct source document has been identified, extracting and interpreting data from a report designed to serve multiple purposes presents its own challenges.

The Association Map (AM) was designed to provide users with an intuitive interface for exploring many-to-many relationships. It extends the D3 concept map, (http://www.findtheconversation. com/concept-map) by allowing the user to specify search parameters.
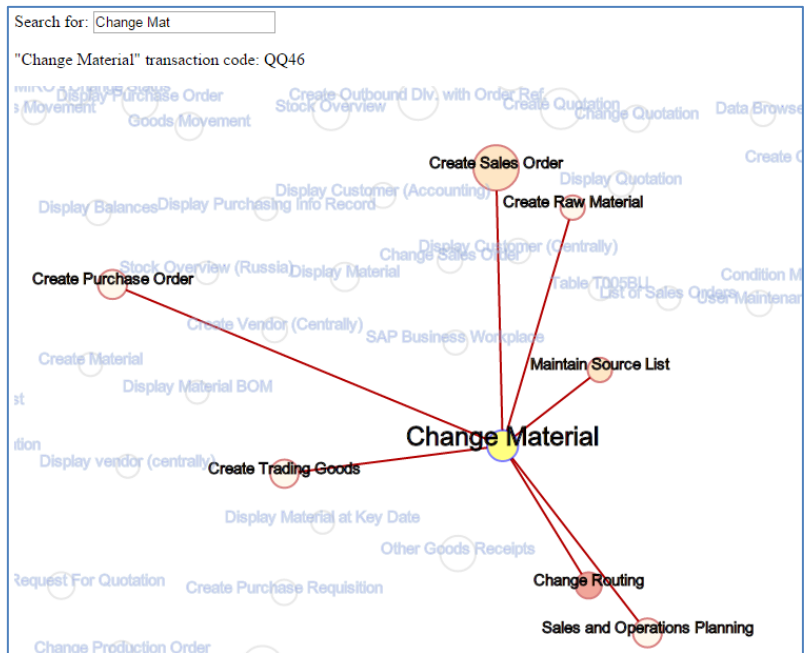

Figure 3: Selected task (in yellow and with larger label) with connected tasks in varying shades of red to reflect frequency with which they co-occur or follow the selected task. The top left corner contains the search interface, the title, and the code of the selected transaction.
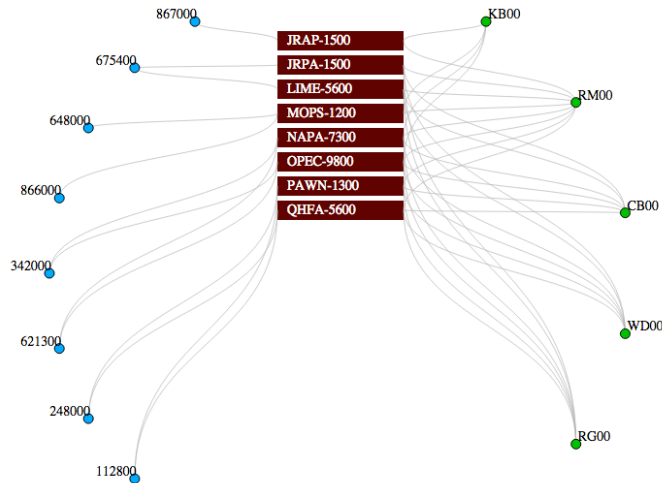
Figure 4: AM visualization of Vendor-Plant-Material relationships. Links to related entities appear in grey. The search interface appears at the top of the visualization.

Figure 4 shows the visualization for exploring relationships between vendors, materials, and plants. Vendors are represented by blue circular nodes, plants by green circular nodes, and materials by brown rectangular nodes. Grey lines connect each vendor to every material it supplies and each plant to every material it stores. Each material can be supplied by multiple vendors and stored in multiple plants.

To zoom in on a particular entity, the user can either point the mouse at the node of interest or enter a search term. For example, Figure 5 shows the resulting visualization when the user either points at the OPEC-9800 material or enters that name in the Material field of the search interface.
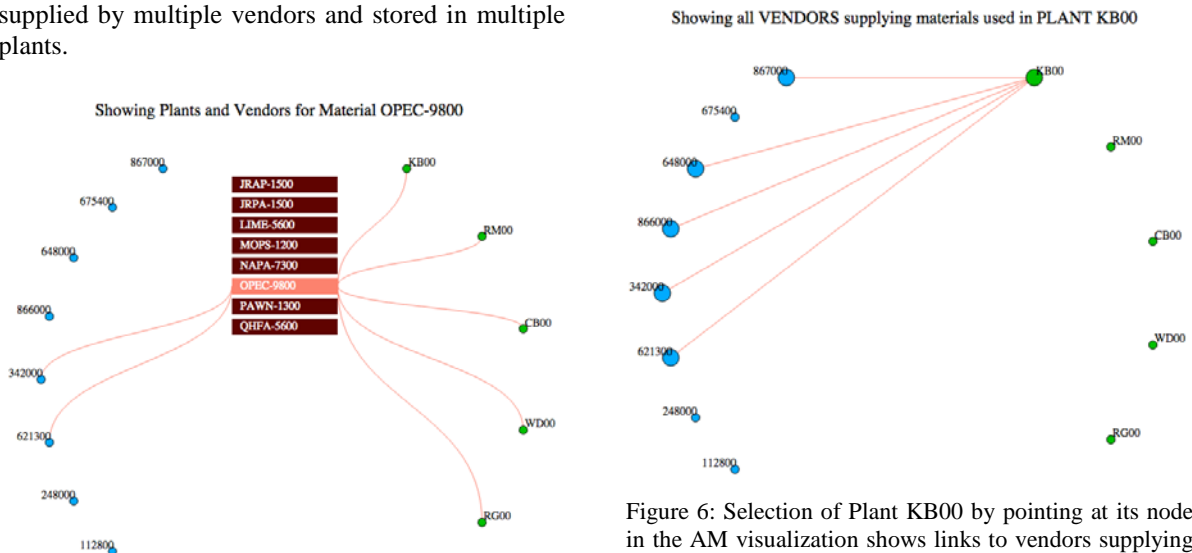

Figure 5: Selection of Material OPEC-9800 from AM search interface or AM visualization. The selected material and links from it appear in pink.

Figure 6: Selection of Plant KB00 by pointing at its node in the AM visualization shows links to vendors supplying materials used by that plant.

Pointing a mouse at a vendor node will display all plants using materials from that vendor, while

entering a vendor identifier to the search interface will show all materials supplied by that vendor. Similarly, pointing at a plant node will show all materials stored by that plant, while entering a plant identifier to the search interface will show all vendors supplying materials to that plant. Figure 6 shows the results of pointing at PLANT KB00. Note that the nodes of vendors supplying materials used by that plant are enlarged.

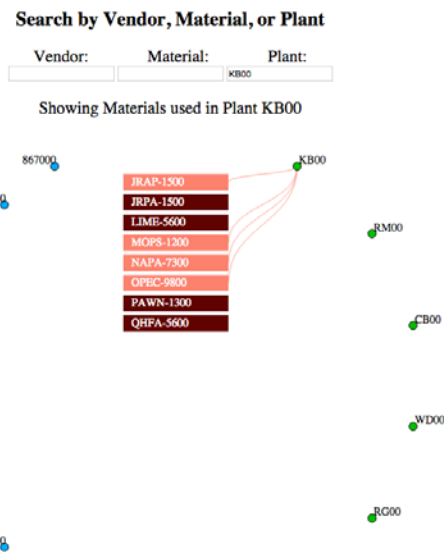Figure 7 shows the display after the user has specified a search on Plant KB00.

Figure 7: Selection of Plant KB00 from the search interface shows all materials stored by that plant.

4 USER STUDY

In this section, we describe an experiment comparing visual interfaces presented in this paper with the navigation and association support interfaces in SAP. Comparisons are in terms of user performance and satisfaction.

4.1 Study Setup

We recruited thirteen study participants from graduate students in a small business university. All students were taking a course that involved the use of SAP. Of the thirteen, ten completed the study according to the instructions provided to them. The three who significantly digressed from the instructions are not included in the analysis presented in this paper. A summary of the

demographic data for the ten participants is presented in Table 1.

Table 1: Demographic data.

Gender	Female: 3 Male: 7
Age	20-30: 8 > 30: 2
Experience with SAP	< 2 months: 6 between 2 and 6 months: 4

Our experiment included two independent parts: the Navigation study and the Association study. Each of these studies included two component parts, one involving an interactive visualization and one involving SAP, as well as a questionnaire (see Figure 8). For each component part, participants were first shown a two-to-four minute video tutorial introducing the specific tool that they would be using. After viewing the tutorial, they were asked to answer a set of questions, each of which required the participant to perform a specific task and, at the end of each task, to enter their answer. The tutorials did not provide answers to these task questions. Each study ended with a questionnaire regarding the user's perceptions of the interfaces they used in the study components.

Part 1 -- Navigation study:
   1.1   DTM Navigation component
     • DTM tutorial (4 min.)
     • 10 task questions
   1.2   SAP Navigation component
     • SAP Navigation tutorial (5.5 min.)
     • 10 task questions
   1.3   Navigation questionnaire (3 questions)

Part 2 -- Associations study:
   2.1   SAP Associations component
     • SAP ME1P report tutorial (2.5 min)
     • 6 task questions
   2.2   AM component
     • AM tutorial (2.5 min)
     • 6 task questions
   2.3   Associations questionnaire (3 questions)

Figure 8: Components of the user study.

As others have done before (Scholtz et al., 2010), we use a mix of quantitative and qualitative measures to capture data about the users' performance and experience. Correctness of responses and time spent answering each question

are used as proxy measures for user effectiveness and efficiency with each of the interfaces (see section 4.2.1). To allow direct comparison between SAP and the visualizations, the task questions in both the Navigation and Associations studies were based on data that was identical in structure but labelled differently. This made it impossible for participants to reuse the answers that they had found earlier.

The Navigation and Association questionnaire responses, discussed in section 4.2.2, provide a qualitative assessment of the users' relative satisfaction with the interfaces.

4.1.1 Navigation study

Both the SAP and DTM components of the Navigation study presented users with five pairs of questions that required finding and selecting a task with a specified name, and then finding a task related (or in the case of DTM, linked) to the previous task, based on the task name or description. Users were given an option to write 'skip' when they were unable to find the answer to the question after spending a few minutes trying. The SAP transaction search operations as well as the way to look for transactions and transaction codes in DTM were demonstrated in the Navigation tutorials (see Figure 7). All participants had knowledge of the SAP menu gained in the previous course work.

The DTM for the study was based on the SAP usage logs from the course in which all participants were enrolled. The DTM included 180 transactions and 345 links. The number of different transactions presented by SAP in a production system is, of course, much larger than 180, but limiting the size of the transaction set to a subset of transactions actually used in an organization is a deliberate part of the design of the DTM. However, the different sizes of transaction sets have no bearing on the study results, as it would be impossible to find the answers to the task questions we presented in a reasonable time in either the DTM or SAP without using the search tools, whose performance is not noticeably affected by the size of the transaction set.

Finding a task in DTM involved either using the search interface or clicking directly on a task circle. To verify that the correct task had been found, participants had to report the task code that was revealed when the task was selected. To find a task in SAP, users had to either locate it in the Menu or use SAP search transactions (SEARCH_USER_MENU or SEARCH_SAP_MENU). Similarly to DTM, users had to report the corresponding task code.

The transaction names in both the DTM and SAP tasks were nearly identical, both based on SAP transaction names. The task codes in DTM were purposely different from the SAP ones to prevent users from reusing the codes they discovered in the SAP part of the Navigation study in their responses in the DTM part.

4.1.2 Associations study

The Associations study tasks asked participants to answer six questions regarding three entities: Vendors, Materials supplied by Vendors, and Plants using the Materials. The questions required different analyses of the data but did not substantially differ in complexity. For evaluation in SAP, we prepared a variant of the SAP Order Price History report (ME1P), which summarizes data from purchase orders in a textual form (see Figure 9). The AM component visualized the same set of Materials, Plants, and Vendors as the report but used different names. The data included eight materials, eight vendors, and five plants involved in approximately 24 purchasing records. Each question asked the user to identify and report a set of items; for example: *"List vendor numbers of all vendors that supply materials that are used in Plant WD00."* The tutorial for AM demonstrated basic features of the visualization; the SAP tutorial briefly described the contents of the report.

Figure 9. A snapshot of two records in an SAP Purchase Order Price History Report used for comparison with AM.

To answer task questions using the AM required that users select an appropriate item via clicking on it or by entering its name in the search interface and observing the linked items. The item names were then entered by the users in the spaces provided for the answers. To obtain the answers in SAP required inspecting the entire report, a process that could be simplified by the use of a selection function, available via the Ctrl-F keyboard shortcut or by clicking on the Find icon in the menu.

4.2 Analysis of Results

The analysis of user performance in the Navigation and Associations studies between SAP and the visualizations is presented next. The participants' responses regarding the usefulness of the visualizations, their preferences regarding the visualizations versus SAP, and suggested improvements are discussed in section 4.2.2.

4.2.1 Quantitative findings

Tables 2 and 3 summarize the results from the Navigation and Association studies, respectively.

Table 2: Summary of the efficiency and effectiveness results of the Navigation study.

	SAP Total Time (Sec)	DTM Total Time (Sec)	SAP/ DTM time ratio	SAP corr. out of 10	DTM corr. out of 10	SAP/ DTM corr. ratio
1	579	163	3.6	6	8	0.8
2	544	222	2.5	0	6	-
3	1266	346	3.7	8	10	0.8
4	615	208	3.0	2	10	0.2
5	455	200	2.3	6	10	0.6
6	482	245	2.0	8	10	0.8
7	1104	259	4.3	9	10	0.9
8	533	234	2.3	3	10	0.3
9	705	192	3.7	2	10	0.2
10	579	222	2.6	5	10	0.5
Ave	**686**	**229**	**3.0**	**4.90**	**9.4**	**0.6**
% correct answers				49	94	
% perfect answers				0	80	

As shown in Table 2, all participants in the Navigation study were at least twice as fast at finding transactions in DTM compared to SAP. On average, the SAP interface required users spend three times as much time as with DTM. In terms of correctness, none of the users provided correct answers to all of the questions in SAP, whereas eight out of ten participants had perfect responses when using DTM. Overall, the SAP interface yielded a 49% correctness rate, versus a 94% rate with DTM. 'Skip' answers, indicating the user had given up, are counted as incorrect here. Out of 51 incorrect

answers with SAP, 29 were 'skips.' In the DTM category, there was one 'skip' answer.

As shown in Table 3 for the Associations study, users came up with answers an average of 2.6 times faster when using the Association Map. The correctness achieved with the use of the SAP report was approximately 67%, with two people out of 10 providing all correct answers. Using AM, correctness was 90%, with five out of ten participants entering perfect answers. There were no 'skip' answers with SAP and one with AM.

Overall, the results demonstrate that across 20 cases involving 10 users and two different tasks, the interactive visualizations yielded greater (in 90% of cases) or equally accurate responses and required less time than SAP in all cases. The higher number of 'skip' responses in the SAP Navigation part indicates the particular difficulty users experience in locating transactions with this interface.

Table 3: Summary of the efficiency and effectiveness results of the Associations study.

	SAP Assoc Time (Sec)	AM Time (Sec)	SAP/AM time ratio	SAP corr. out of 6	AM corr. out of 6	SAP/AM corr. ratio
1	373	240	1.6	5	6	0.8
2	507	191	2.7	3	6	0.5
3	622	293	2.1	6	6	1.0
4	606	78	7.8	4	5	0.8
5	280	175	1.6	1	5	0.2
6	320	90	3.5	5	5	1.0
7	351	150	2.3	6	6	1.0
8	353	206	1.7	2	5	0.4
9	621	428	1.4	3	4	0.8
10	246	193	1.3	5	6	0.8
Ave	**428**	**205**	**2.6**	**4.00**	**5.40**	**0.7**
% correct answers				66.7	90	
% perfect answers				20	60	

4.2.2 Qualitative findings

After the participants completed the tasks in each of the two studies, they were asked to respond to a short questionnaire about their experiences. The three questions asked after the Navigation study are

shown in Figure 10, while the three asked after the Associations study are in Figure 11.

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1. Would you use the Dynamic Task Map for navigating to a desired transaction, if it were embedded within an ERP interface and if clicking on a transaction circle would open the transaction? Why or why not?

2. How would you compare the Dynamic Task Map to the way of finding transactions in SAP in terms of ease of use and usefulness?

3. Do you have any suggestions for improving the Dynamic Task Map interface?

Figure 10: Navigation study questionnaire.

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1. Would you use the Association Map for answering questions about plant-material-vendor associations if it were embedded within an ERP interface? Why or why not?

2. How would you compare the Association Map to the way of finding the same information in SAP in terms of ease of use and usefulness?

3. Do you have any suggestions for improving the Association Map interface?

Figure 11: Associations study questionnaire.

Navigation Study: Responses to the navigation questionnaire revealed that participants were generally pleased with DTM and typically preferred it to SAP. In response to **Question 1**, eight of the 10 participants replied that they would use DTM. The primary reason given was that it was much easier to find transaction codes than with SAP because you can see the connections between transactions. Participants also commented that DTM is intuitive and logical. Of the two dissenters, one said s/he would try it but had difficulty getting overlapping names to spread out. The other thought s/he would use it at first but would then likely switch to searching with SAP once s/he had more experience.

In comparing DTM to SAP (**Question 2**), nine participants strongly preferred DTM. Comments included that it was much easier to use, faster for searching, and more useful and intuitive. The one less enthusiastic comment was that neither DTM nor SAP are ideal for searching, but that DTM does provide better visualizations of steps and how they are connected.

Participants had many useful suggestions in response to **Question 3**, including having DTM remember and highlight the user's prior searches, spreading the transactions out more for easier reading, and adding logical groupings of nodes (such as production planning, inventory, etc.).

Associations Study: Responders to the associations questionnaire were also pleased with AM. In response to **Question 1**, the majority of participants commented on how easy it was to use for finding associated information. Seven would use AM with no qualifications given, one would use it but would prefer an excel report with pivoting, one would potentially use it, and another expressed concern about how crowded it might get when used with a full production system. Other comments included how well it organizes the information and how it "took away the tedious scrolling that SAP required."

The responses to **Question 2** were all positive, with eight participants noting that AM was much easier to use than SAP, one commenting on how it saves time, and another on how it is clearer and less "search-heavy."

Some of the suggestions in response to **Question 3** included preserving the view when the mouse moves away from an association and making the drill-down "sticky" so that the user can capture the information more easily, automatic report generation/file download from the selected associations, and improved support for searching over multiple fields.

5 DISCUSSION

The analysis of the data from this study shows that for novice users performing common tasks, such as finding transactions or associations among master records, interactive visualizations considerably decreased task completion time and increased accuracy compared to traditional ERP interfaces. Notably, participants were introduced to DTM and AM at the time of the study, while the SAP interface was already familiar to them through previous coursework. The users' greater success rate in our experiment at completing the tasks with visual interfaces that were previously unfamiliar to them suggests that interactive visualizations may enable novice users to complete more difficult tasks without the extensive training and experience with the system that would otherwise have been required.

The qualitative data analysis suggests that even as users become more experienced with the system, they may still benefit from interactive visualizations. Visualizations presented here can incorporate more advanced options, such as grouping transactions in DTM together by business function and facilitating easier data download from AM for report generation. Such options would improve the fit between the user, the business needs, and the

interface capabilities, which is an essential element of ERP implementation success (Hong and Kim, 2002).

The results of the study presented here suggest that interactive visualizations are one way that ERP vendors can increase the usability of their products, which is becoming more and more important in today's ERP marketplace (King, 2012). These visualizations are more intuitive to learn and easier to use and thus should reduce the need for extensive and expensive training. The users' improved perception of the ERP system and greater confidence in their ability to perform the necessary tasks with it would lead to less resistance and increase acceptance of a newly implemented system. Last, but not least, the interactive interface would result in productivity improvements by reducing the time it takes to complete tasks and improving accuracy. As a result, the need for re-work and the associated delays would be minimized.

The main limitation of the study stems from the fact that our visualizations were implemented as standalone interfaces, while the SAP interfaces for the same tasks were embedded in the context of a larger system. Thus, some inefficiency in performing tasks with SAP could be due to the users' attention being distracted by the numerous features of the interface. Another limitation is the small number and the uniform background of the study participants. Although a larger, more diverse sample population would provide a more complete assessment of the benefits of interactive visualizations for different user groups, our sample is appropriate for an initial usability study targeted at novice users.

6 CONCLUSIONS

In this paper, we advance ERP usability research by investigating the use of interactive visualizations for navigation and association-related tasks in enterprise systems. Our results showed that novice users performed those tasks faster and at least as accurately when using DTM and AM visualizations than when using SAP. These results empirically corroborate the view expressed by users in surveys (Lambeck et al. 2014a, 2014b) that useful visualizations decrease the complexity of ERP interfaces, enabling more productive use of the system. Users also overwhelmingly preferred the visual interfaces to the SAP alternatives.

In future work, we plan to fine-tune and enhance the existing visualizations based on feedback from the study. We will use the improved interfaces to investigate the impact of different features on user performance and user perceptions in more detail and with a larger sample population.

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