Interactive Visualizations for Workplace Tasks

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Abstract. Enterprise Resource Planning (ERP) systems pose usability challenges to all but the most sophisticated of users. One challenge arises from complex menu structures that hinder system navigation. Another issue is the lack of support for discovering and exploring relationships between the data elements that underlie transactions performed with the system. We describe two dynamic, interactive visualizations, the Dynamic Task Map and the Association Map, which were designed to assist users in ERP system navigation and data exploration activities. We present two laboratory studies comparing the use of these visual components to SAP interfaces. Results from an initial empirical evaluation revealed performance gains when using the visual components compared to the default SAP interface. A follow-up study showed users' overall preference for the visual interface, although no significant user performance differences were detected. User-reported mental effort associated with the visual interface was lower compared to the SAP table-based presentation.

Keywords: Dynamic Visualizations, Interactive Visualizations, Enterprise Systems, ERP.

1 INTRODUCTION

In the first issue of Interactions, Myers [1] 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 [2].

Even with considerable investments in training, 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 ([3]–[8]).

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 [2]. A recent Gartner report [9] 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 [10]. While such techniques are widely used by the visual analytics community [11], interactive visualizations are not prevalent in ERP systems.

In this paper, we present empirical studies of two interactive visualizations designed to aid ERP system users in navigation and data exploration tasks [12]. 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.

In an initial exploratory study, ten 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 [13]). 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.

Although users in the exploratory study performed significantly better when using avisualization, it is possible that the performance gains were due to the visual interfaces containing no data that was irrelevant to the tasks while the SAP interfaces displayed a significant amount of additional data. A follow-up study was conducted to more closely investigate user performance with and attitudes towards the AM visual interface under conditions in which both interfaces showed equivalent data. This study, with over 80 participants, revealed no significant differences in user performance on assigned tasks. The participants did, however, report less mental effort needed for solving tasks with the visualization compared to the table-based representations in SAP. The vast majority of users expressed their preference for the Association Map compared to SAP.

In the next section of this paper, we review related work. This is followed by a description of the visualization components under investigation. The exploratory user

study setup is detailed, and results from that study are then presented and discussed. Next, the follow-up associations study and its findings are described 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, [5], [14]–[16]). 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. [3] 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 [6]–[8].

Rather than tackle ERP usability issues directly, however, research has often focused on the "human factor." Hurtienne et al. [17] describe 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. [18] 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 [19].

A survey of 184 users with different experience levels working with a variety of ERP systems revealed that being able to find the desired enterprise functionality is still a problem across all user experience levels [7]. 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 [8].

Recently, visualizations have gained popularity as tools for process navigation, discovery, and mining [20]. Hipp et al. [21] 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. [22] 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.

Outside of the ERP domain, studies indicate that complex decision problems in general can benefit from visualizations such as visual query interfaces, which are superior to text-based interfaces especially when larger data and solution sets are involved ([23]). As the objective complexity of the task increases, however, decision-makers employ different problem-solving processes. This results in a more nuanced relationship between the information presentation format and task performance, with visualizations being better for some but not all complex tasks [24].

Despite the wealth of evidence regarding their potential benefits, visualizations have yet to be integrated in any significant way into commercial 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 are 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 [12].

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 user.

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 system 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.

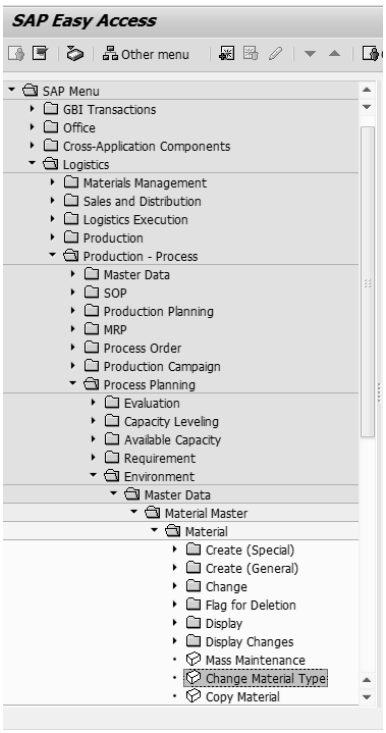

Fig. 1. SAP Easy Access Menu expanded to locate the Change Material Type transaction

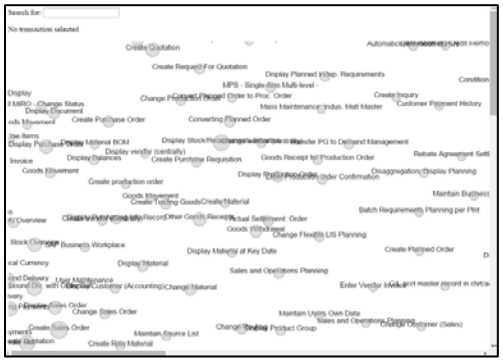

Fig. 2. DTM visualization of all transactions. No nodes are selected. The search box appears in the top left corner.

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.

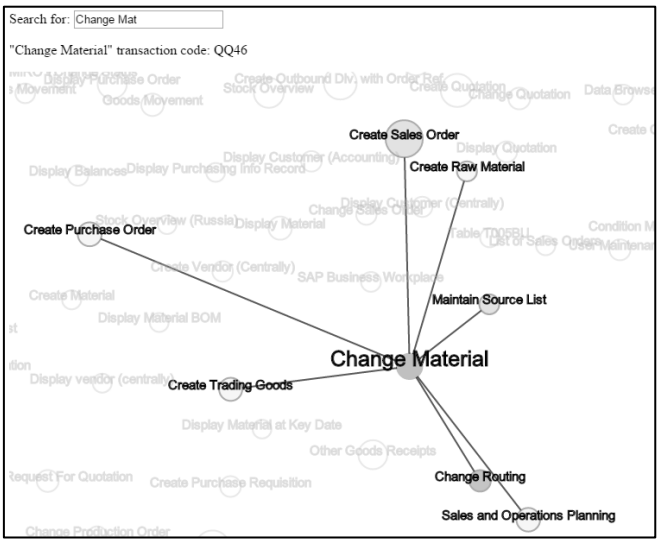

Fig. 3. Selected task (in yellow and with larger label) with connected tasks in varying shades of red to reflect frequency with which they co-occur or follow the selected task. The top left corner contains the search interface, the title, and the code of the selected transaction

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 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. Pointing a mouse at a vendor node, for example, 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 5 shows the results of pointing at PLANT KB00. Note that the nodes of vendors supplying materials used by that plant are enlarged. Figure 6 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 7 shows the display after the user has specified a search on Plant KB00.

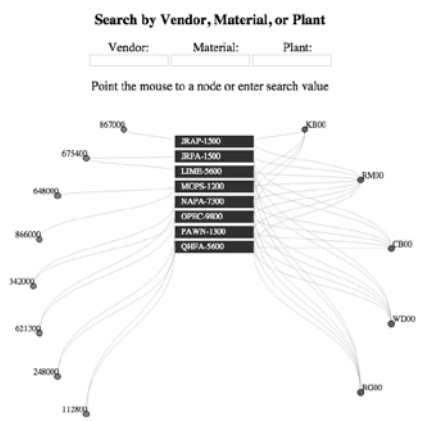

Fig. 4. AM visualization of Vendor-Plant-Material relationships. The search interface appears at the top of the visualization.

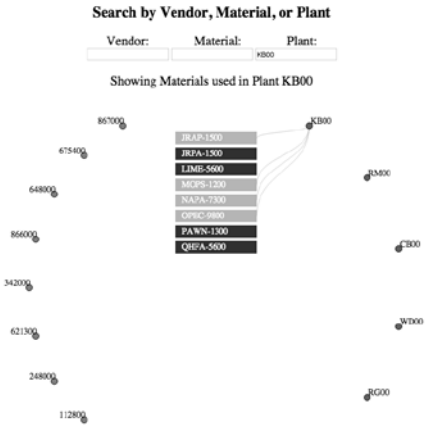

Fig. 5. Selection of Plant KB00 from the search interface shows all materials stored by that plant.

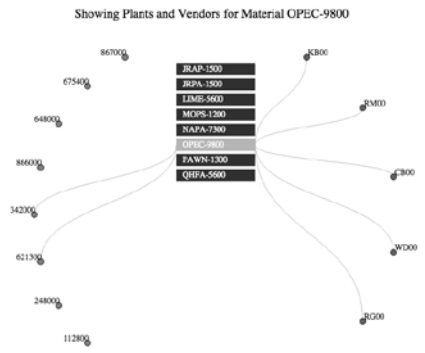

Fig. 6. Selection of Material OPEC-9800 from AM search interface or by pointing at it in the AM visualization.

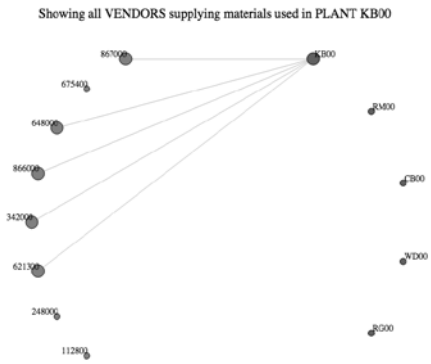

Fig.7. Selection of Plant KB00 by pointing at its node in the AM visualization shows links to vendors supplying materials used by that plant.

4 EXPLORATORY USER STUDY

In this section, we describe an experiment comparing visual interfaces presented in Section 3 with the navigation and association support interfaces in SAP. Comparisons are in terms of user performance and satisfaction.

4.1 Exploratory 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 Associations 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.

As others have done before [5], 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 Associations questionnaire responses, discussed in section 4.2.2, provide a qualitative assessment of the users' relative satisfaction with the interfaces.

Part 1 -- Navigation study:	Part 2 -- Associations 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)	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)

Fig. 8. Components of the exploratory user study.

4.1.1 Navigation study. Both the SAP and DTM components of the Navigation study presented users with five pairs of questions. These questions required finding and selecting a task with a specified name, followed by finding a task related (or in the case of DTM, linked) to the previous task, based on the task name or its 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 8). All participants had knowledge of the SAP menu gained in their 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 this, 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. 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 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, with both based on SAP transaction names. The task codes in DTM were purposely different from those in SAP 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.

To answer task questions using 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. To obtain the answers in SAP required inspecting the entire report. This process 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.

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

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. 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 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**	

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 appear in Figure 11.

1.1 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?
1.2 How would you compare the Dynamic Task Map to the way of finding transactions in SAP in terms of ease of use and usefulness?
1.3 Do you have any suggestions for improving the Dynamic Task Map interface?

Fig. 10. Navigation study questionnaire.

2.1 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?
2.2 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?
2.3 Do you have any suggestions for improving the Association Map interface?

Fig. 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 1.1**, 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 1.2**), 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 1.3**, 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 2.1**, 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 2.2** 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 2.3** 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, providing automatic report generation/file download from the selected associations, and improving support for searching over multiple fields.

4.3 Summary of Findings from the Exploratory Study

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 prior coursework. The users' greater success rate 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 be required.

The qualitative data analysis suggests that even as users become more experienced with the system, they may still benefit from interactive visualizations. The visualizations presented here could 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 ([19],[25]).

5 FOLLOW-UP ASSOCIATIONS STUDY

To further investigate the differences in user performance with and attitudes towards traditional, table-based format representations of data and the Association Map, we performed a follow-up study. We customized the default SAP interface and altered the original AM interface so that the content presented by both interfaces in this study was identical, though presented in a different way. We call these two interfaces SAP-C (for a Customized version of SAP) and AM-N (for the New version of the AM).

5.1 Interfaces: SAP-C and AM-N

The customized SAP interface displaying Purchase Order Price history is shown in Figure 12. Compared to the non-customized version shown in Figure 9, SAP-C strips away the details of association not shown in the Association Map, showing each association instance as a single row of three values: Vendor, Material and Plant. Depending on which column is used for sorting the records, repeated values of either Material, Vendor or Plant are omitted. In contrast, the default interface used in the exploratory study (Figure 9) for each association instance displays a small table with multiple cells containing additional details of the association.

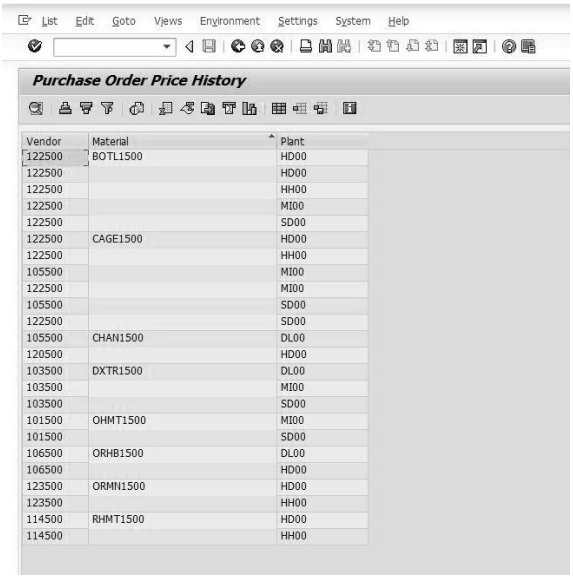

Fig. 12. A screenshot of the SAP-C interface.

The new AM interface, AM-N, includes four different views: one showing all associations and the remainder showing associations for a selected Vendor, Material, or Plant, respectively (see Figures 13-16).

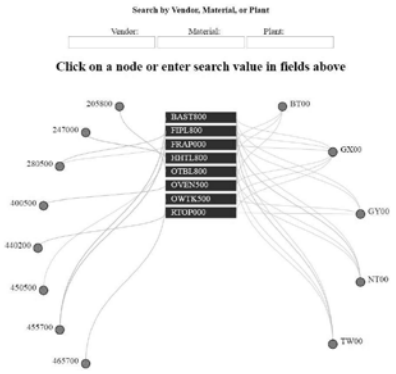

Fig. 13. AM-N interface showing all associations.

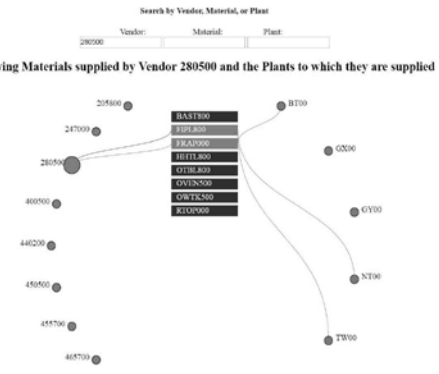

Fig. 14. AM-N interface showing associations for the selected Vendor (on the left).

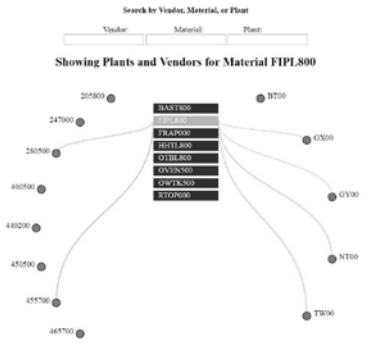

Fig. 15. AM-N interface showing associations for the selected Material (in the middle).

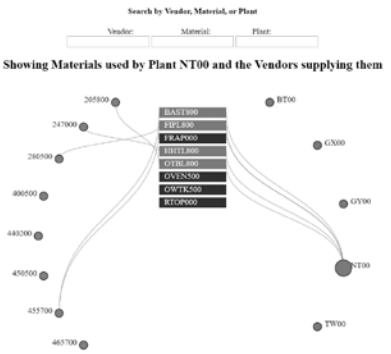

Fig. 16. AM-N interface showing associations for the selected Plant (on the right).

Throughout the remainder of this section, we refer to SAP-C and AM-N as SAP and AM for simplicity.

5.2 Follow-up Associations Study Setup

This study was conducted as part of the coursework in an undergraduate course on ERP configuration and a graduate course in Business Process Management, both of which involve the use of SAP. The design of the study was similar to the exploratory Associations study (see Sections 4.1 and 4.1.2). Participants were asked to answer a set of nine questions, each of which required the performance of a specific task. At the end of each task, users entered their answer and also indicated how much mental effort was required to complete the task on a scale from 1 (very, very low) to 9 (very, very high). The study concluded with a questionnaire regarding the participants' perceptions of the interfaces they had used.

Differently from the exploratory study, half of the participants were first shown a two-to-four minute video tutorial introducing the specific tool that they would be using, while the remaining participants did not receive any training. The tutorials did not provide answers to the task questions. In order to minimize potential biases, the participants were randomly assigned to the training or non-training group; within each group, they were further randomly assigned to see either the AM interface or the SAP interface first.

Of the hundred and six participants, eighty six completed the study according to the instructions provided, with 83 participants providing usable answers for each task question, and 86 providing usable answers to interface perception questions. Twenty responses that were incomplete or digressed significantly from the instructions were not included in the analysis presented below. A summary of the demographic data is presented in Table 4.

Table 4. Demographic data for the follow-up Association Map study.

Gender	Female: 41 Male: 45
Age	21-24: 69 25-28: 17
Experience with SAP	< 2 months: 44 between 2 and 6 months: 26 between 7 and 11 months:14 between 1 and 2 years: 1 over 2 years: 1

5.3 Analysis of Results

5.3.1. **Quantitative findings.** Tables 5 and 6 summarize the quantitative results from the follow-up Association study. To understand the data, a variety of analyses were performed using the R programming language.

As shown in Table 5, users took between 7 and 8 minutes on average to complete the tasks (across all nine questions) using either interface, with or without training. A visual inspection of this data indicates users without training took slightly less time using the AM interface, while users with training took slightly more time using this interface than with SAP. There seems to be more variability in the data in the non-training groups than in the training groups with either interface and more variability for the SAP interface than for AM, with or without training. To see if these differences are statistically significant, we ran t-tests as well as a series of general linear models with total time as a dependent variable and type of system (AM versus SAP), training, and question (1-9) as independent variables. None of these more advanced tests indicated significant effects, with the exception of one test for a complex question in the non-training group. Based on this experiment, the time to complete the tasks is, therefore, similar for both SAP and AM, with or without training. Further testing will be required to understand if significant differences occur when users have to answer more complex questions.

Table 5. Summary of the efficiency and effectiveness results of the follow-up Associations study.

	Total time to complete all 9 questions Average *(st dev)* across participants (sec)		Mean question time (across all 9 questions) Average *(st dev)* across participants (sec)		Number of correct answers (out of 9) Average *(%)* across participants		% of perfect answers (all 9 correct) % across participants	
	AM	SAP	AM	SAP	AM	SAP	AM	SAP
With training	448.62 *(196.18)*	444.65 *(280.69)*	49.85 *(54.48)*	49.41 *(78.26)*	8.40 *(93%)*	8.28 *(92%)*	55%	50%
Without training	466.57 *(228.97)*	471.95 *(360.24)*	51.84 *(55.70)*	52.44 *(79.99)*	7.86 *(87%)*	7.88 *(88%)*	40%	37%

The correctness achieved with the use of the SAP report was 92% with training and 88% without training, with 50% of the participants in the training group and 37% in the non-training group providing all correct answers. Using AM, correctness was 93% with training and 87% without training, with 55% of the participants in the training group and 40% in the non-training group providing all correct answers. Chi-square tests confirmed that correctness is significantly higher with training ($p=0.006$) and when using the AM interface ($p=0.0001$).

Table 6. Summary of the mental effort results of the follow-up Association study.

	Mean mental effort (across 9 tasks) Average *(st dev)* across participants (1-9 scale)	
	AM	SAP
With training	2.64 *(1.65)*	3.28 *(1.72)*
Without training	3.05 *(1.77)*	3.73 *(1.87)*

Furthermore, as shown in Table 6, the average value of the mental effort reported by users receiving no training (on a 1-9 scale, across all tasks) was 3.05 when using the AM interface and 3.73 when using the SAP interface. The average value of mental effort reported by users receiving training was slightly lower overall, with the AM interface still requiring less effort than the SAP interface (average of 2.64 vs 3.28). To see if these differences are statistically significant for each task, we ran a general linear model with mental effort as a dependent variable and type of system (AM versus SAP), training, and question characteristics (difficulty, answer length) as independent variables. The results indicate that mental effort is significantly lower for simple questions and for the training group, and significantly higher when using the SAP interface (with 0.001 significance for all these variables).

5.3.2 Qualitative findings. The participants were asked to answer questions based on their experiences with SAP and AM after the task completion process. These questions included perceptions of the visual and interactive aspects of the two interfaces, perceptions of sorting and searching capabilities, ratings of the interfaces over various attribute ranges, selecting which interface would be preferred for future work, and short answer responses focused on comparing and evaluating the interfaces. Following are the findings from each of these categories of questions.

Perceptions of the visual and interactive aspects: After completing the set of tasks using either of the systems, participants were asked to rate the following attributes with respect to the system that had just been used. A seven-point Likert scale ranging from 1 (disagree strongly) to 7 (agree strongly) was employed. Table 7 shows the results of this ranking. As can be seen, participants found that the SAP interface was

more complex, more crowded, and displayed too much information as compared to the AM interface. The AM interface was found to be more interactive than that of SAP.

Table 7. Comparison of visual and interactive aspects of SAP and AM interfaces.

Statement	Polarity	SAP		AM	
		Mean	SD	Mean	SD
The interface was complex.	-	3.66	1.53	2.91	1.48
The interface was crowded.	-	3.89	1.67	3.25	1.70
The interface was interactive.	+	3.59	1.69	5.73	1.28
The interface displayed too much information.	-	3.61	1.62	2.77	1.36

Sorting and searching capabilities: After completing the set of tasks with SAP, participants were asked if "The **sorting** feature of SAP was useful to me in answering the questions." Since AM does not have a sorting feature, participants were asked to rank the following statement after completing the set of tasks with that interface: "Having data presented in **sorted order** was useful to me in answering the questions." In both cases, participants were asked if the **search** feature of the particular interface was useful to them in answering questions. The choices available to users in answering all of these questions were 1 (I was not aware of this feature) followed by a Likert scale ranging from 2 (Disagree Strongly) to 8 (Agree Strongly).

More participants were unaware of the sorting and searching features of SAP vs. AM. The mean and standard deviation values for the sorting feature (SAP) and the sorted order of data (AM) shows there was not much difference in ratings of usefulness, with 5.58 M, 2.5 SD for SAP and 5.91 M, 2.07 SD for AM (note that the features being compared were not exactly the same). Among those who were aware of the searching features, far more participants found AM's search capability to be useful than SAP's (3.63 M, 2.3 SD for SAP, 5.91 M, 2.08 SD for AM).

Attribute comparisons. Participants were also asked to rate the use of each interface for performing tasks along five perceived enjoyment dimensions [25] using a seven-point scale. The results of these ratings are shown in Table 8. The ratings for AM were higher than for SAP along all of these dimensions

Table 8. Ratings of of SAP and AM interfaces for performing tasks along five dimensions.

Using the interface for task performance was:	Polarity	SAP		AM	
		Mean	SD	Mean	SD
Unexciting (1) to Exciting (7)	+	3.36	1.59	4.91	1.37
Dull (1) to Neat (7)	+	3.38	1.77	5.34	1.40
Not fun (1) to Fun (7)	+	3.23	1.60	4.92	1.38
Unappealing (1) to Appealing (7)	+	3.66	1.70	5.31	1.42
Boring (1) to Interesting (7)	+	3.33	1.65	5.06	1.56

Interface comparisons and evaluations: Lastly, participants were asked 5 short answer questions, as shown in Figure 17. Eighty-five of the 86 participants provided usable answers to all these questions.

3.1 How would you compare the Association Map to the way of finding the same information in SAP?
3.2 Assuming you have access to both the Association Map and the SAP interface, which one do you intend to use the next time you have to perform similar tasks? (choices of AM, SAP, or Undecided)
3.3 Please explain your answer to the above question regarding which interface you intend to use.
3.4 Do you have any suggestions for improving the Association Map?
3.5 Do you have any suggestions for improving the SAP interface?

Fig. 17. Short answer questions.

In answering **Question 3.1**, eighty-one of the participants made positive comments about how the AM interface compares to SAP for finding information. "Interesting," "user-friendly," "visually appealing," and "easy to use" were some of the terms that were frequently used. Eleven participants described negative aspects of AM, including the lack of a sort function, limited search options, and a confusing presentation when links are tangled, making it less suitable for larger data sets. Two of those eleven had nothing positive to say about AM and felt that the results shown by SAP were clearer, while a third thought that both interfaces were confusing.

Eighteen participants had positive observations about SAP, including its suitability for working with large amounts of data, its sort feature, and the straightforward and professional way the results are presented. Thirty participants made negative comments about SAP, noting it was more difficult to use and confusing.

The following comment illustrates the overall perspective of many of the respondents: "Using the AM was a lot more interactive and dynamic. Using a more graphic way to represent the relationships as opposed to SAP made finding the information a lot easier. Also, the AM allowed for the searches to be broader than SAP. In SAP, for example, it is not as easy to search both a vendor and a plant in order to look for the materials. In SAP you have to do a lot of the work yourself when looking for different relationships or information."

In answering **Question 3.2** on system preferences, 73 participants chose AM, eight participants chose SAP, and five were undecided. The most common reasons given in **Question 3.3** for preferring AM focused on the interface being easy to use, requiring less effort, and being more visually appealing and fun. As summarized by one participant, "AM's interface is user-friendly and more appealing to the eyes. I liked the visible and clear search boxes. Also, with how the page was set up the vendor, material, and plant data was very easy to view and decipher. Using AM made the physical work and mental work I had to do in order to reach the answers much less." Several participants also commented on the interactive features of the AM interface and how the visualization helped them understand the relationships between the data elements.

Two of the eight participants who preferred SAP indicated a preference for AM in their answer to question 3 on intended use, and a third (confusingly) stated that "Because AM is more straightforward than SAP, I prefer SAP." Of the remaining five, two thought SAP was clearer, two noted its sorting feature, and one preferred it because s/he has used it before so is more familiar with it. Of the five undecided participants, one commented on liking SAP during prior use, one would need more experience with both, and the remaining three indicated that it would depend on the amount of data involved.

Sixty-eight participants offered suggestions for improving the AM interface in response to **Question 3.4**. These included expanding the search functionality, hiding all but the relevant data after a selection has been made, allowing data points to be draggable so that connections can be more easily viewed, revealing related information when an item is clicked, using additional color coding for differentiating between data elements and for highlighting links, allowing the user to specify the range of variables for limiting the amount of data displayed, and using straight rather than curved lines for clarity.

Sixty-nine participants offered suggestions for improving SAP in response to **Question 3.5**. These included removing repeated data after sorting, allow sorting on more than one field at a time, highlight the columns being sorted and indicate the sorting direction, make both sorting and searching functionality more obvious, provide single-click sorting capability, include visualizations of tabular data and make it more interactive (like AM), offer a "quick hide" option to remove excess information, color code the data for easier identification, highlight the more useful menu options, and streamline the number of menu items and label them more clearly.

5.4 Summary of Findings from the Follow-up Associations Study

The follow-up comparison study of AM versus a customized table-based SAP interface containing exactly the same content showed no advantage of either interface in terms of task completion time. The fact that the data in the SAP table all fit within one screen is important, because it implies that no scrolling was necessary. The users in our study were relative novices in SAP and were all exposed to AM for the first time. It is possible that for our novice users, the tasks reached the complexity at which spatial representations are not superior to other methods, or that our participants were making the types of accuracy/effort trade-offs identified in previous research [24].

In terms of user attitudes towards both interfaces, users reported that less mental effort was required when working with the visual interface than with the SAP table. They also largely preferred the visual interface to the tabular one, expressing it in free form comments as well as using a variety of measures of user satisfaction. Many participants attributed their preferences to less physical and mental work required for finding answers to questions using the Association Map. Study participants reported several opportunities for improving both interfaces.

6 CONCLUSIONS AND FUTURE WORK

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 the default SAP interfaces. In a closer comparison of a tabular representation of associations within SAP versus the Association Map, users reported lower mental effort when working with the AM visualization, while performing with similar speed and accuracy. Users also overwhelmingly preferred the visual interfaces to the SAP alternatives. These results empirically corroborate the view expressed by users in surveys ([7], [8]) that useful visualizations decrease the complexity of ERP interfaces, enabling more productive use of the system.

The results of the studies 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 [2]. These visualizations are more intuitive to learn and easier to use; they should therefore 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 likely lead to less resistance and increased acceptance of a newly implemented system. Last, but not least, DTM would potentially result in productivity improvements by reducing the time it takes to locate task interfaces.

The main limitation of our studies 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 inefficiencies in performing tasks with SAP could be due to the users' attention being distracted by the numerous features of the interfaces. Another limitation is the novice status and the relatively young age of the study participants. Although a 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 initial usability studies targeted at novice, entry-level ERP users.

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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