Exploring Functional Areas in Adaptive Information Presentation to Improve Business Intelligence

Group 3

1. INTRODUCTION

Information in reports and dashboards are commonly designed using a one-size-fits-all approach, i.e. not taking into account differences among users. Such information may be difficult to understand and users may be overloaded with displayed data, thereby affecting timely decision-making (Yelizarov & Gamayunov, 2014). Efforts have thus been made in order to take into account differences among users. Namely, a significant amount of work has been done surrounding adaptive data visualizations using eye gaze data from eye-trackers as user input (Lallé et al., 2021; Steichen et al., 2013; Göbel et al., 2018), to model various user properties including user focus, visual literacy, preferences, and comprehension within different settings and regarding performance on different tasks.

Little of this work has been done in a business intelligence (BI) context where the usage of reports and dashboards to present business information is mean to provide an easy to use and easy to understand application so that an individual can subsequently make intelligent decisions (Hansoti, 2010; Jourdan et al., 2008). Furthermore, little research has been done specifically focusing on how adaptations can be implemented to present data based on a user's functional area, e.g. departments such as operations, marketing, and human resources (Chuma, 2010). Hansoti (2010) has described how different functional areas in an organization use information differently to fit their needs; it is thus of considerable importance for key decision-makers within each functional area to sufficiently comprehend the information presented and evaluate the appropriate actions.

As such, this work aims to explore how a user's functional area can be used to adapt information presentation within reports and dashboards for business intelligence by designing and implementing a prototype for a web-based application that tailors the presentation of information (i.e. data visualization and text) based on a user's functional area. The scope of this work focuses solely on presenting a proof of concept for a fictitious e-commerce company with fictitious quarter one sales data, given its preliminary nature. Our work contributes to existing research by focusing on BI, a widespread context of usage for information presentation, and the role of functional areas which have not yet been extensively investigated for adaptation.

2. RELATED WORK

2.1. Need for Adaptation

There is extensive evidence that short-term states such as cognitive overload can affect a user's performance with tasks relating to information presentation and decision-making (Yelizarov & Gamayunov, 2014; Brunken et al., 2003; Cao et al., 2009; Zhuang, 2018), signifying that support to address this difficulty would be beneficial. Yelizarov & Gamayunov (2014), in particular, address the impact of cognitive overload on decision-making in safety critical systems such that users of these systems can be overloaded by all of the data represented in the interface, slowing down the time it takes for the users to make decisions and affecting their performance in monitoring tasks. Furthermore, cognitive load has implications in the use of multiple modalities (e.g. text and images) for decision-making and learning (Brunken et al., 2003; Cao et al., 2009) based on the *dual-coding theory* and the *dual-channel theory*. The dual-coding theory from Paivio (1986) suggests that auditory material (e.g. written or spoken text) and visual material (e.g. pictures or graphics) are processed and mentally represented in separate but interconnected systems. The dual-channel theory is derived from Baddeley's model of working memory (Baddeley, 1974) and posits that working memory has separated stores for auditory and visual information where each store has limited capacity. Thus, in order to better use the capacity of working memory in total, it is preferable to enable these two perception channels to work collaboratively on a given perception task (Cao et al., 2009). For example, it has been shown that students learn better when their learning material combines animation and speech than when it combines animation and on-screen text since physically separated animation and text split a student's visual attention, thus increasing load in the visual store (Mayer & Moreno, 2003). Zhuang (2018) then explores the impact of visual complexity in data presentation on cognitive load and subsequent decision-making accuracy, confirming a threshold for which cognitive overload hampers decision accuracy for contexts including business intelligence.

Moreover, existing research has investigated how data visualizations can be more effective in conveying information, including the improvement of user comprehension (Quadri et al., 2014; Midway, 2020). Quadri et al. (2014) explored comprehension by examining the alignment between designers' communicative goals and what the end users see, or interpret, in a given visualization; it was found that what data visualization designers predict for their end users often differs from the patterns people intuitively comprehend in a visualization. This then indicates opportunities for providing support to users to improve comprehension based on specific user properties instead of estimates from designers. Various principles and practices have been presented to better communicate visual information (Midway, 2020; Telea, 2014). However, although these principles and practices provide a foundation for effective visual design, adaptation maintains potential to tailor visual information to the needs and contexts of specific audiences.

2.2. Adaptation for Business Intelligence

Research has shown that how well organizations can understand and leverage their data to gain useful insights and support decision-making at all levels can significantly affect their capability to deliver prudent and efficient outcomes (Bai et al., 2013; Chen et al., 2012; Bai et al., 2011). Moreover, BI systems often use various visualization techniques to present the data and support user tasks including navigation, retrieval, query, discovery, and interpretation (Bai et al., 2013). Thus far, however, only the work by Bai et al. (2013) on contextual factors within BI systems has been used to drive adaptation, in this case creating visualization subsystems that enable end users to create, manipulate, transform, or dispose of visualization solutions. This suggests that more research is needed to explore adaptations within a business intelligence context, which this work aims to provide.

3. ADAPTIVE APPLICATION

3.1. Dataset

We chose to use the scenario of an e-commerce company, given that such an organization would likely have an abundance of data being stored digitally for use in a business intelligence context. We chose to do so for a fictitious company for ease of use and resulting time constraints. Employee names for the e-commerce company, to be used for application login and subsequent adaptation, were derived from Blumberg (2016); organizational structure of the company, to be used for identification of employee positions and functional areas and subsequent adaptation was obtained from Bernhart (2020). Data used for displayed content was chosen to focus on sales as a generalizable category typically used in business intelligence, which were similarly fictitious for ease of use, given the proof of concept and preliminary nature of this work.

3.2. Application Design

Our proposed prototype tailors highlighted text, bars, and layout corresponding to the current (i.e. logged in) user's properties of position and functional area, where each user and their properties are retrieved from a database. The prototype aims to improve end users' understanding of organizational data to then improve decision-making in terms of reducing cognitive load and the time it takes for users to make decisions, and increasing comprehension. The adaptations were chosen simply to demonstrate the proof of concept for tailoring information presentation based on the user's position and functional area, and are not indicative of hard requirements for these properties. Given that a user study was unable to be carried out to better understand adaptation requirements as we did not have access to survey employees within a business organization, adaptations were based on our prior experience working within such organizations. The web application includes two main sections, 1) a sales key performance indicator (KPI) dashboard and 2) a more detailed sales report in order to demonstrate adaptations for multimodality information presentation in different ways. Initial mockups were designed prior to development and project proposal in Figma. See Figures 1 and 2 for mockups of the KPI dashboard for a sales associate and chief financial officer, respectively; see Figures 3 and 4 for mockups of the quarter one sales report again for a sales associate and chief financial officer, respectively.

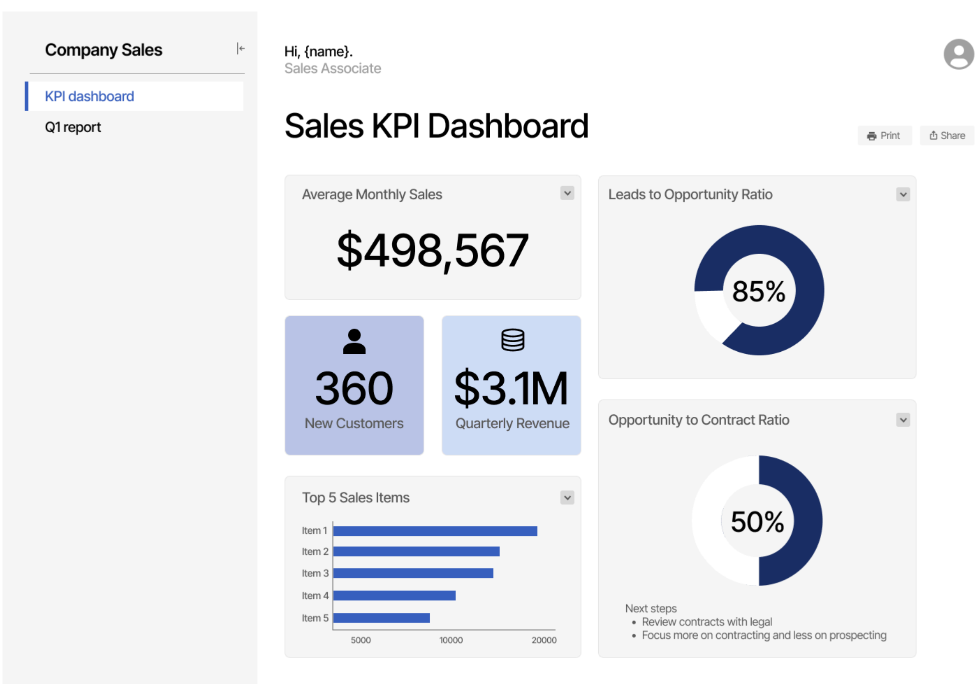

Figure 1. Design mockup for a sales KPI dashboard with a layout tailored to a sales associate position.

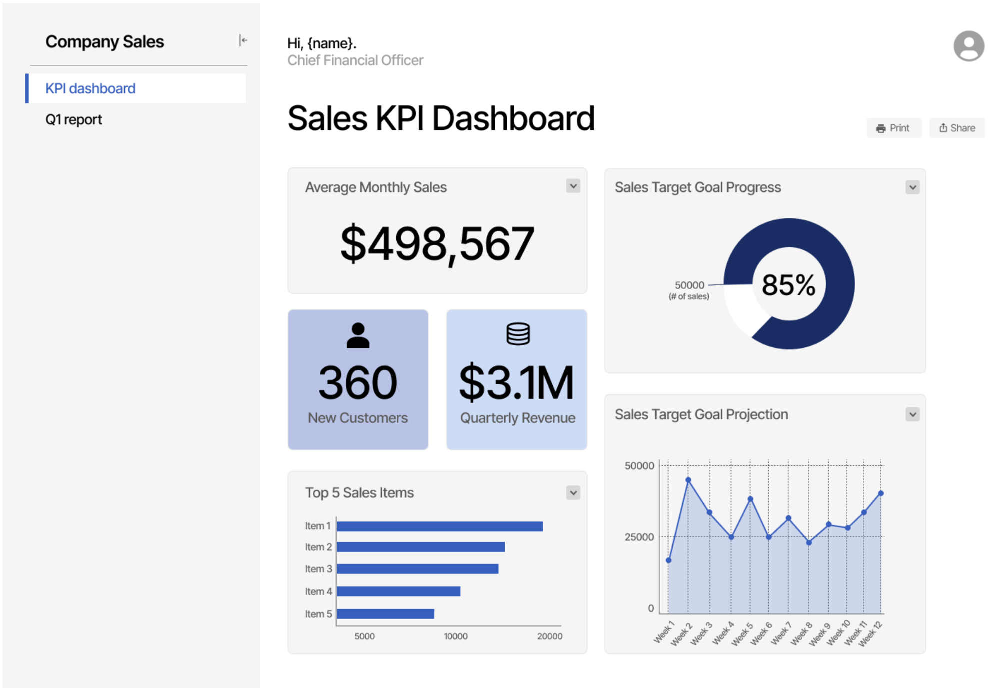

Figure 2. Design mockup for a sales KPI dashboard with a layout tailored to a chief financial officer position.

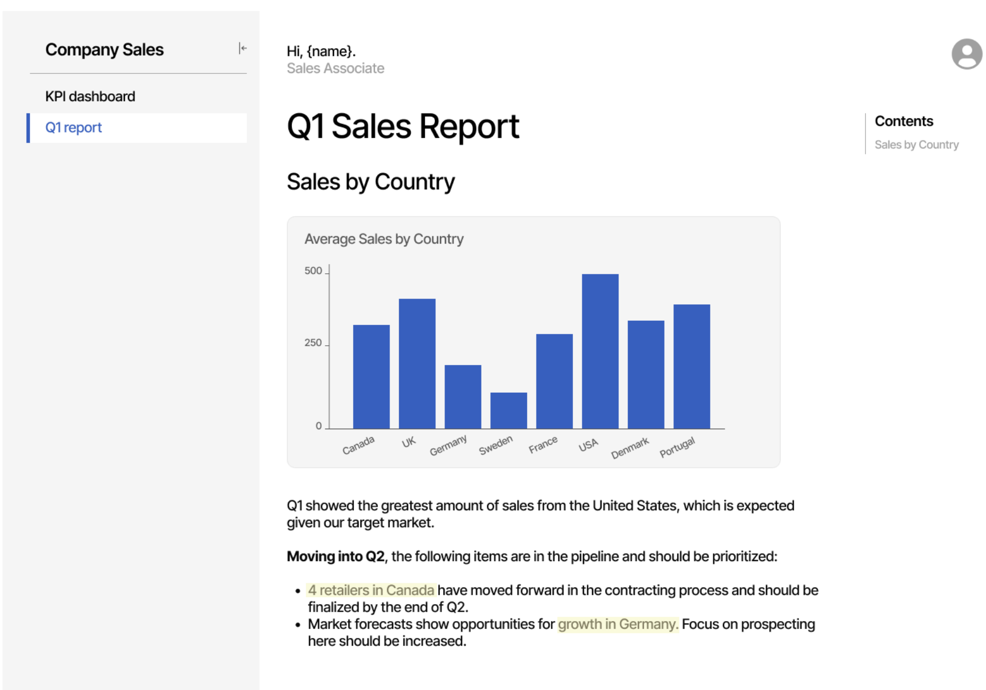

Figure 3. Design mockup for a quarter one sales report with text and highlighting tailored to a sales position.

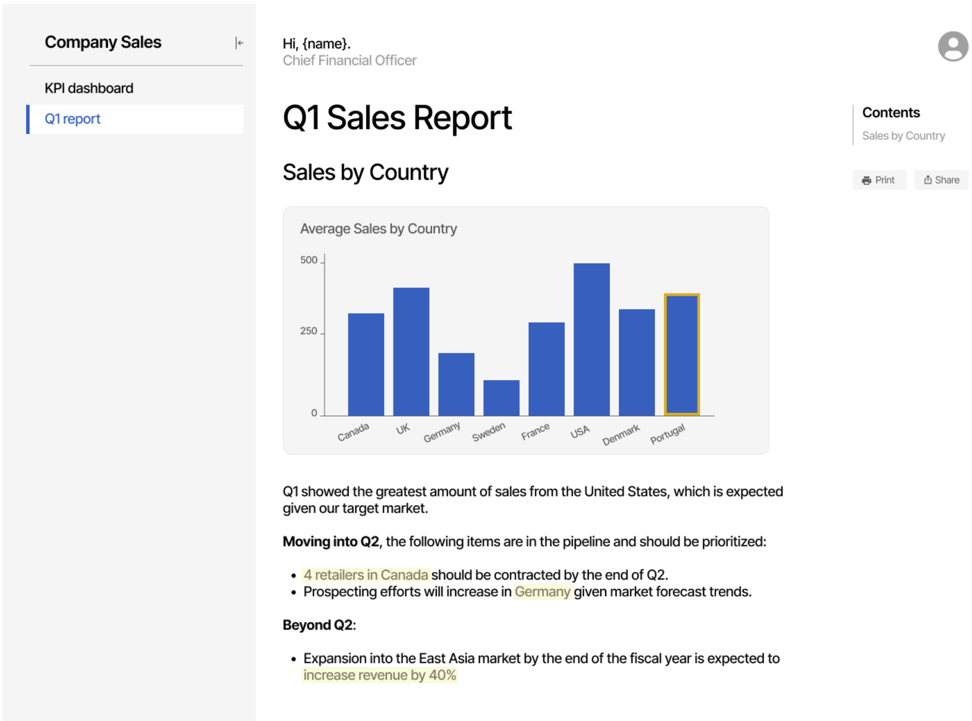

Figure 4. Design mockup for a quarter one sales report with text and highlighting tailored to a chief financial officer position.

3.3. Application Development

The web application was built with Next.js for the frontend component, Node.js for the backend component, MongoDB for the database, Tailwind CSS for styling, and D3.js for data visualization. Next.js and Node.js were chosen given our own familiarity with these tools from previous work with web applications. MongoDB was chosen given that it is a NoSQL database and thus is more of a general data store that can have a flexible schema. User authentication was implemented with NextAuth.js and the Prisma connector to read and write users to and from the MongoDB database.

To implement the adaptations, simple conditional rules were used. See Appendix 1 for a link to the Github repository containing the full code. For the report component of the application, the following conditions were used to demonstrate the proof of concept. If the current user was part of the ‘C-Suite,’ i.e. Chief Executive Officer (CEO), Chief Financial Officer (CFO), and so on, the overall approach was to emphasize high-level information and focus on both growth and strategy; the bar with the highest value in the bar chart was outlined with a border which correlated with the highlighted text in yellow directly beneath the chart, different parts of the text were highlighted, and more text was given to do so. If the current user was part of the marketing functional area, the adaptations aimed to provide actionable insights and focus on next steps specific to marketing (i.e. improve decision-making timeliness); the bar with the lowest value in the bar chart was outlined with a border which corresponded to the next steps given, and different parts of the text were highlighted. Similar to marketing, if the current user was part of the finance functional area, the adaptations aimed to provide the user with actionable insights and next steps specific to finance, and so the next steps were written out and different parts of the text highlighted. For the dashboard component of the application, the adaptations focused on differences in layout, where if the user was part of the C-Suite, the layout was tailored to again emphasize information in a high-level overview and focus on growth. Both the report and dashboard components of the app had a default view in which the adaptations built upon that view. If a user was not logged in, this default view was automatically displayed for both components. These adaptations are of course not exhaustive of all adaptations possible or relevant in a given organization, but aim to show the capability of a prototype that can implement these adaptations.

3.3. Adaptive Loop

The application focuses on the user model and inference for adaptation aspects of the adaptive loop. User modelling consists of the user’s functional area and position, retrieved from storage in the database. Inference for adaptation consists of the conditional rules, and the adaptive behavior is the tailoring of the text and visualizations. See Figure 5 for a graphical representation of the adaptive loop for the application.

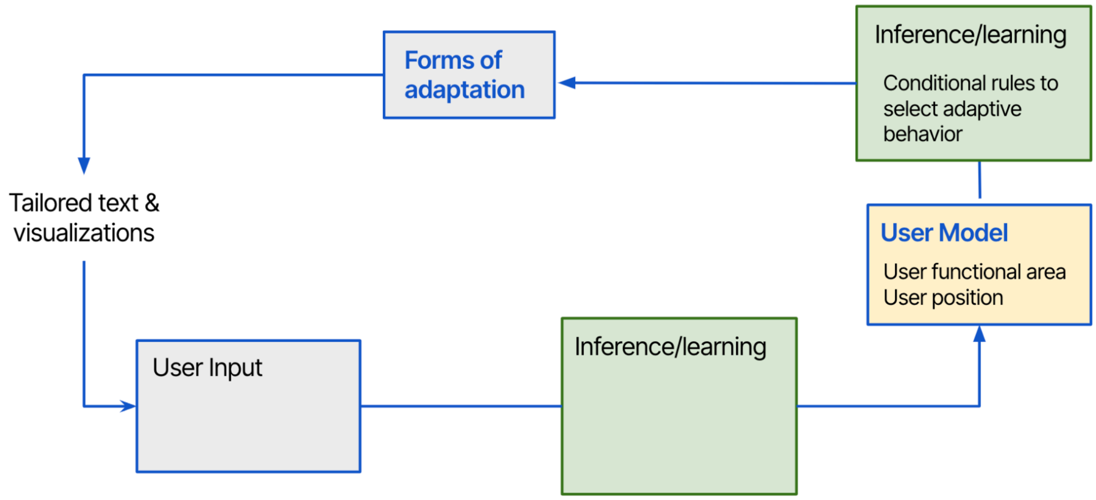

Figure 5. The adaptive loop for the application.

4. RESULTS

The prototype was implemented as described above in section 3.3. See Figures 6 and 7 for the different visualization and text presentations in the report, respectively, and Figures 8 and 9 of the different layouts in the dashboard for the C-Suite and default views, respectively.

Figure 6. The different report views based on functional area in regards to text and bar chart highlighting.

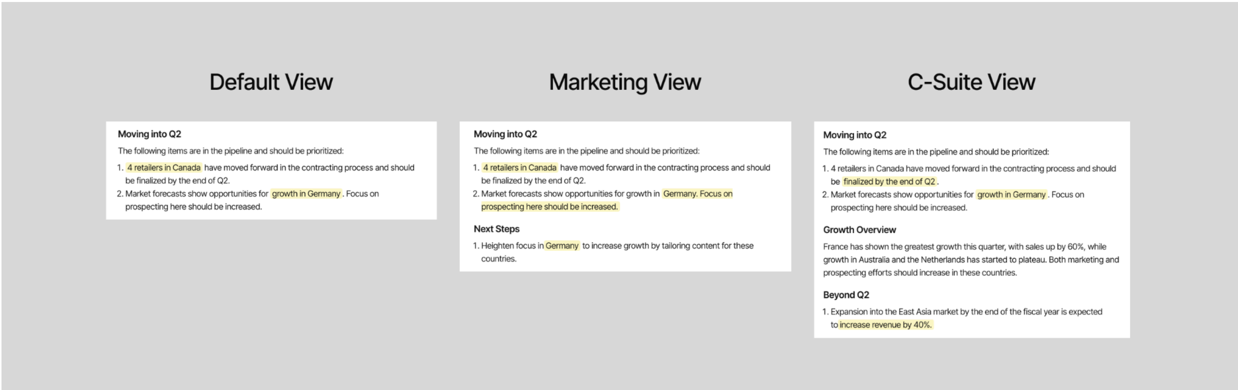

Figure 7. The different report views based on functional area in regards to text and text highlighting.

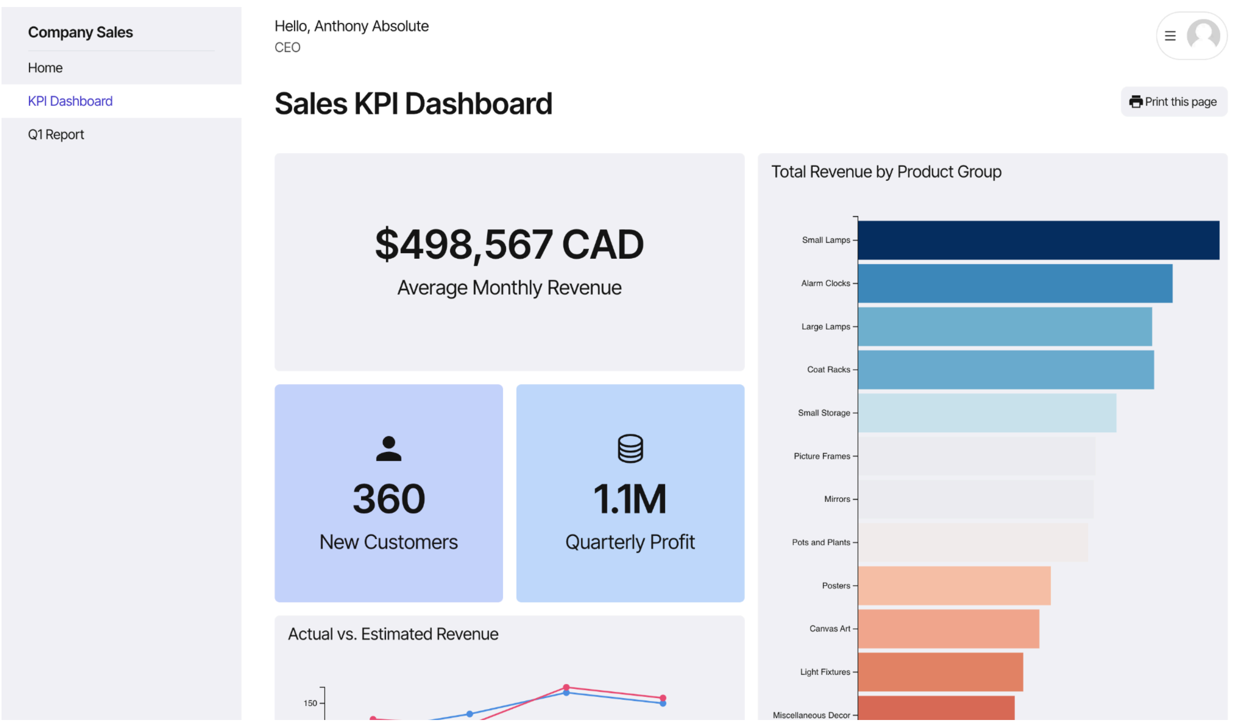

Figure 8. The C-Suite dashboard layout.

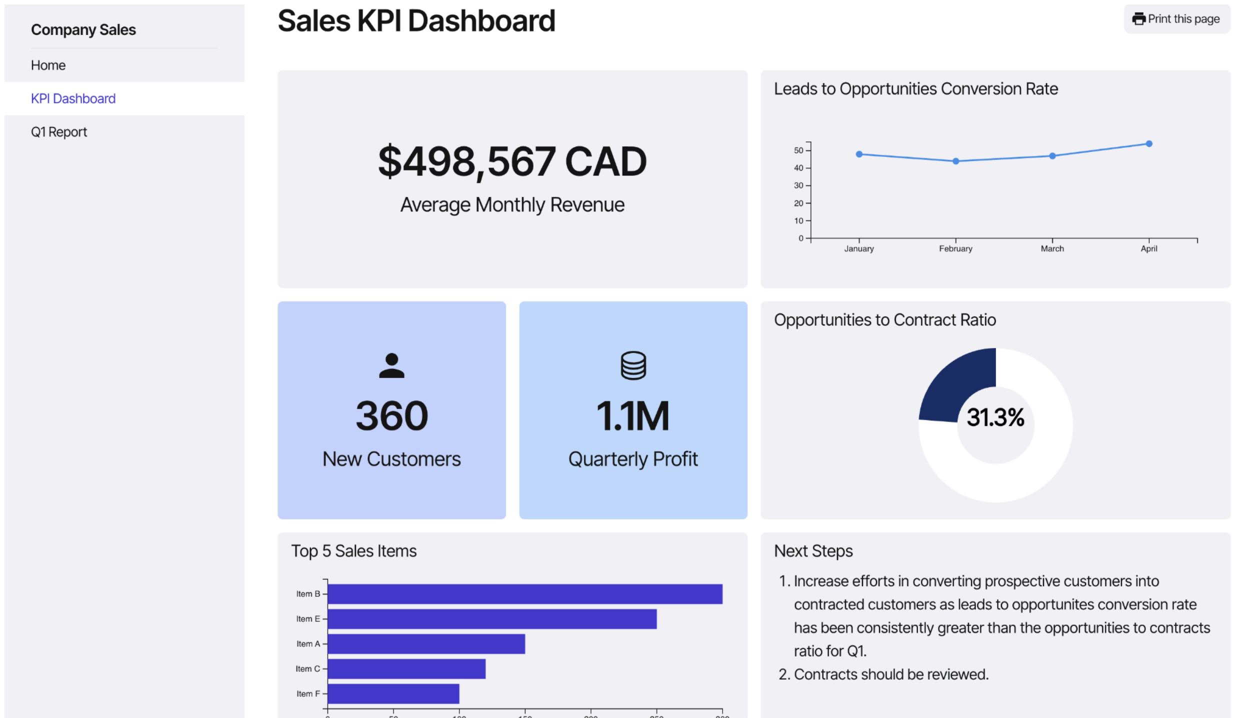

Figure 9. The default dashboard layout.

5. DISCUSSION

5.1. Limitations and Future Work

A primary limitation was time and resource constraints. In order to more definitively identify requirements for adaptations, e.g. what aspects should be focused on for a given functional area instead of choosing based on simple prior knowledge, a user study should be conducted with employees in an organization that use BI tools for decision-making. Furthermore, in order to formally evaluate the impact of the adaptations on users' cognitive load and comprehension, and understand if and how the adaptations are beneficial, a user study would also be of importance as the prototype and adaptations were unable to be evaluated in this way. Additionally, because this work was a proof of concept only, not all functional areas had conditions for adaptation. Future work should examine the necessity and relevance of doing so, and include in implementation. The adaptive loop was also unable to be closed and very primitive user modeling was done simply by retrieving user information from the database. More sophisticated user modeling and completion of the adaptive loop should be worked towards in the future. Finally, our adaptations were only driven by a user's functional area and position.

Future work should also examine how adaptation can be based on individual preferences, and could potentially include options for customization.

5.2. Conclusion

Our proof of concept prototype demonstrates the capability of building a web application with tailored information presentation based on a user's functional area and position. This is significant considering the lack of research surrounding adaptive information presentation in a BI context. Furthermore, this has implications for environments other than the specific use case of e-commerce given the widespread reach of BI in organizations of varying sectors (Chen et al., 2012). We contribute to previous work by showing that functional area-driven adaptation is possible and has the potential to improve decision-making, although more work should be done regarding user-informed adaptations, formal evaluation, closing the adaptive loop, and the inclusion of other user properties to drive adaptations.

6. REFERENCES

Baddeley, A.D. and G.J. Hitch: 1974, 'Working Memory'. *The Psychology of Learning and Motivation: Advances in Research and Theory*. pp. 47-89.

Bai, X. D. White, and D. Sundaram: 2013, 'Context adaptive visualization for effective business intelligence'. *15th IEEE International Conference on Communication Technology.* pp. 786-790.

Bai, X. D. White, and D. Sundaram: 2011, 'Purposeful Visualization'. *2011 44th Hawaii International Conference on System Sciences.* pp. 1-10.

Bernhart, J.: 2020, 'A BluePrint for Success for Online Success: How to Structure Your Ecommerce Team'. *Bernhart Associates*. Accessed from https://bernhart.com/ecommerce-organizational-structure/.

Blumberg, N.: 2016, 'List of Fictional Characters'. *Britannica*. Accessed from https://www.britannica.com/art/list-of-fictional-characters-2045983.

Brunken, R., J. L. Plass, and D. Leutner: 2003, 'Direct Measurement of Cognitive Load in Multimedia Learning'. *Educational Psychologist.* pp. 53-61.

Cao, Y., M. Theune, and A. Nijholt: 2009, 'Modality effects on cognitive load and performance in high-load information presentation'. *Proceedings of the 14th international conference on Intelligent user interfaces,* Sanibel Island, Florida. pp. 335-344.

Chen, H., R. Chiang, and Storey, V. C.: 2012, 'Business Intelligence and Analytics: From Big Data to Big Impact'. *MIS Quarterly.* p. 1165.

Chuma, L. L.: 2020, 'The Role of Information Systems in Business Firms Competitiveness: Integrated Review Paper from Business Perspective'. *International Research Journal of Nature Science and Technology*. pp. 29-42.

Göbel, F., P. Kiefer, I. Giannopoulos, A. Duchowski, and R. Martin: 2018, 'Improving Map Reading with Gaze-Adaptive Legends'. *Proceedings of the 2018 ACM symposium on eye tracking research & applications.* pp. 1-9.

Hansoti, B: 2010, 'Business Intelligence Dashboard in Decision Making'.

Jourdan, Z., R. K. Rainer, and T. E. Marshall: 2008, 'Business Intelligence: An Analysis of the Literature', *Information Systems Management.* pp. 121-131

Lalle, S., D. Toker, and C. Conati: 2021, 'Gaze-Driven Adaptive Interventions for Magazine-Style Narrative Visualizations'. *IEEE Trans. Visual. Comput. Graphics*. pp. 2941-2952.

Mayer, R.E. and R. Moreno: 2003, 'Nine Ways to Reduce Cognitive Load in Multimedia Learning'. *Educational Psychologist.* pp. 43-52.

Midway, S. R.: 2020, 'Principles of Effective Data Visualization'. *PATTER*.

Paivio, A.: 1986, 'Mental Representations: A Dual Coding Approach'. *Oxford University Press*.

Steichen, B., G. Carenini, and C. Conati: 2013, 'User-Adaptive Information Visualization - Using Eye Gaze Data to Infer Visualization Tasks and User Cognitive Abilities'. *Proceedings of the 2013 international conference on Intelligent user interfaces.* pp. 317-328.

Telea, A. C.: 2014, 'Data Visualization: Principles and Practice, Second Edition'. *CRC Press*.

Quadri, G. J., A. Z. Wang, Z. Wang, J. Adorno, P. Rosen, and D. A. Szafir: 2024, 'Do You See What I See? A Qualitative Study Eliciting High-Level Visualization Comprehension'. *arXiv*: arXiv:2402.15605.

Yelizarov, A. and D. Gamayunov: 2014, 'Adaptive Visualization Interface That Manages User's Cognitive Load Based on Interaction Characteristics'. *ACM International Conference Proceeding Series*. pp. 1-8.

Zhuang, K. L.: 2018, 'Cognitive Load and Decision Accuracy: A Study of Visual Complexity in Data Presentation'. *International Journal of Business Management and Visuals*. pp. 6-9.

APPENDIX 1

Link to Github repository for full code: https://github.com/leesadie/cogs303