Survey and classification of recommendations for evaluating visualization and usability quality criteria in Business Intelligence systems

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***Abstract*—The growing reliance on data for strategic decision-making intensifies the relevance of Business Intelligence (BI) tools. In this context, it is crucial to ensure the quality of user interactions and visualizations provided by these platforms to the end-user. However, there are gaps in the evaluation of BI tools quality in terms of usability and visualization quality criteria, especially with respect to the heuristic evaluation method. This paper presents partial results of an ongoing doctoral research project aimed at filling this gap. Through a literature review, we surveyed 22 recommendations for BI tools regarding visualization and usability aspects. We also mapped these recommendations to the visualization heuristics of Morroni et al. to identify similarities between groups of recommendations. We expect to use this classification to generate a new set of heuristics for evaluating BI systems, with the goal of enabling the improvement of these systems' quality.**

***Index Terms*—Business Intelligence, Heuristic Evaluation, Data Visualization, Usability.**

I. INTRODUCTION

Business intelligence (BI) systems have become important tools for assisting analysts in processing, analyzing, and simplifying large volumes of data. This capacity is increasingly essential for organizations to optimize their decision-making processes [1]. At its core, BI can be considered the set of all methods and tools for translating raw information into a meaningful and convenient format [2]. It involves the development of processes, technologies, systems, and methodologies that analyze data to extract new insights [3]. By combining business analytics, data mining, data visualization, and robust data infrastructure, BI empowers organizations to make data-driven decisions [4]. A key element in this process is the use of effective data visualizations within BI tools, which play a pivotal role in supporting decision making by mitigating the perceived uncertainty and complexity of information, thus fostering the generation of more robust knowledge [5].

Given the wide availability of BI tools on the market and their use for data analysis, it is relevant to ensure that the technical robustness of these systems effectively translates into visualizations that are not only accessible but also genuinely facilitate understanding and evidence-based decision-making. This requires considering both the quality of user interaction with these tools and the quality of the visualizations they generate. Therefore, the use of evaluation methods capable of analyzing these quality aspects becomes necessary.

Among the many evaluation methods provided by the fields of Human-Computer Interaction (HCI) and Information Visualization (InfoVis), Heuristic Evaluation (HEv) is a well-known inspection technique used to analyze system usability without direct user participation [6]. This technique allows for the identification of potential interface and interaction problems by applying a recognized set of usability heuristics, such as those postulated by Nielsen [6]. When applied during the software development or maintenance cycle, HEv can detect flaws that could compromise the user experience and the clarity of the information presented, even before formal user testing.

Despite the use of HEv to assess interactive and visualization systems in general, the literature review conducted as part of this research identified a significant gap: the lack of a set of heuristics specifically designed to evaluate BI software in terms of both usability and visualization quality. This creates an opportunity to develop or adapt heuristics that consider the unique aspects of BI tools. Although guidelines exist for evaluating the usability of general software and the quality of visualization systems, no heuristic sets were found that are specifically dedicated to analyzing these two complementary aspects within BI systems, which are vital for effective data exploration and decision-making support.

Based on this gap, the goal of this paper is to present a collection of recommendations from the BI literature for evaluating systems in this area, gathered and grouped by thematic similarity. The results of this survey will support future stages of the ongoing doctoral research, which propose a new set of heuristics focused on usability and visualization quality criteria, intended for use in HEv of BI systems.

This paper is organized as follows. Section 2 addresses relevant aspects regarding BI tools and the relationship among BI, usability, visualization, and HEv. It also covers a literature review on works related to our research. Section 3 details the

research methodology used for creating the list of recommendations to BI tools. Section 4 presents the 22 recommendations for BI tools that we identified in the related works, grouped by similarity. Section 5 concludes the paper, highlighting its contributions and pointing out directions for future research, including the validation and testing of the proposed set.

II. RESEARCH BACKGROUND

In this section, we discuss the importance of usability and visualization in BI tools, distinguish BI tools from dashboards, and explore the concept of HEv. We also present the works that served as a basis for the collection and organization of the BI recommendations.

A. Usability and Visualization in BI Tools

Despite their robust processing and analysis capabilities, the effectiveness of a BI system is intrinsically linked to its usability, as demonstrated by the perspective of Muppidi et al. [7]. The literature highlights that ease of use is not merely a desirable attribute but a determining factor for these platforms' success, directly impacting user adoption rates and productivity.

Villamarín and Diaz Pinzon [8] emphasize that ease of use and learnability are crucial for consistent tool usability, reinforcing that good usability is rooted in ease of learning, efficiency of use, and user satisfaction. For Few [9], [10], when a BI system is intuitive and easy to operate, analysts can dedicate their time to interpretation and decision-making instead of expending excessive effort on tool manipulation. Ekanem [2] shows that good usability in a BI system is not limited to aesthetics or navigation but directly translates into the user's ability to interact effectively with the data lifecycle.

In addition to usability, the BI tools ability to generate effective data visualizations is a key aspect in transforming data into knowledge. Well-designed visualizations transform complex datasets into clear and understandable visual representations, allowing users to identify patterns, trends, and anomalies with speed and accuracy [11]. Furthermore, effective visualizations reduce the user's cognitive load and minimize ambiguity in data interpretation [12].

The quality of a BI system is a multi factor that extends beyond data accuracy and technical robustness. The combination of good usability and visualization are not just desirable attributes; they are determining factors for the effective extraction of value from data and for the achievement of an organization's strategic goals [13].

B. BI Tools vs. Dashboards

Although the expressions "BI tool" and "dashboard" are often used interchangeably, it is crucial to distinguish between them. This differentiation is central to the scope of this paper, which focuses on evaluating the quality of BI tools themselves, rather than just the visual artifacts they produce.

BI tools encompass the data infrastructure, analysis engines, modeling capabilities, and software interfaces that allow users to interact with data, build queries, create visualizations, and generate reports [14]. They are the platforms where data intelligence work is performed, spanning from data input to the final export of information.

Dashboard is a visual representation of the most important information from a dataset, presented in a consolidated format that often features key performance indicators (KPIs) to track strategic goals [15]. According to Bach et al. [16], dashboards are more than mere data mirrors; they are visual lenses created to concisely monitor the most critical information. Few [10] and Kitchin [17] emphasize that a dashboard's effectiveness lies in consolidating essential information into a single screen for quick monitoring, serving purposes that range from strategic to operational. Dashboard's quality, while important, depends on the robustness of the BI tools that creates it. Flaws in the tool's usability or visualization capabilities can compromise the final dashboard, even with correct underlying data. This is why this work focuses on evaluating BI tools, aiming to improve their usability and visualization quality criteria.

C. Heuristic Evaluation in the Context of BI Tools

HEv is a widely recognized inspection method for identifying usability problems in user interfaces. Developed by Nielsen and Molich, this technique involves experts analyzing an interface based on a set of usability general principles (heuristics) that guide intuitive and efficient design [18]. The 10 heuristics proposed by Nielsen [6] have since become a benchmark, enabling the detection of potential interaction flaws even before formal user testing. Its application within the software development lifecycle can effectively mitigate usability issues.

In the context of BI, the relevance of this technique has been reinforced by studies that are able to adapt its principles to this specific domain. Ekanem [2] highlights usability challenges in BI tools, validating the need for specialized heuristics for complex tasks such as data preparation. Similarly, Liu et al. [13] argue that the evaluation should focus on how the interface facilitates decision making. Beelders and Kotzé [19] advocate HEv as a method that complements user testing, capable of identifying usability problems quickly and efficiently, particularly in the early stages of software development. These works collectively demonstrate that HEv remains a necessary tool, provided it is adapted to the unique challenges of BI tools.

D. Related Work

This section reviews the literature to justify the creation of new heuristics for quality in BI platforms. The analysis reveals a gap: most studies evaluate usability or visualization in isolation, with few offering a combined set of criteria. We also identified works with recommendations for building dashboards, but they do not focus on evaluating the underlying BI tools.

1) Usability: In the usability area, the works consistently use the heuristics of Nielsen and Mack [6], [18], demonstrating a clear concern for the ease with which users interact with BI

tools. The impact of Nielsen's work extends beyond its original application; his heuristics serve as a basis for numerous studies and are frequently used as a starting point for creating new, more specific and contextualized heuristic sets.

2) Visualization: In the field of InfoVis, several works have sought to evaluate the visual and interactive quality of systems. Authors such as Freitas et al. [20], Amar and Stasko [21], Zuk and Carpendale [22], Scapin and Bastien [23], and Forsell and Johansson [24] have proposed many heuristics for this context. Oliveira and Silva [25] summarizing the main contributions of these studies. The discussion in the field has since evolved to debates on how these heuristics should be applied. Santos et al. [26] argued that they should not be excessively specific, as this could distract evaluators from more general problems. Väätäjä et al. [27] highlighted the importance of clear and concise documentation, suggesting that heuristics should include examples of violations and be logically grouped. Tarrell et al. [28] presented classifications for the development of visualization heuristics, categorizing them into three classes: process-based, performance-based, and framework-based. Zhu and Gumieniak [29] proposed a computer-assisted evaluation method based on heuristics but underscored the need for human inspection, as many heuristics are too abstract to be automatically verified. Bach et al. [16] reinforce the idea that, for complex domains such as data visualization, structured and specific tools are necessary, proposing design patterns for dashboards, as the application of generic usability principles is insufficient. Setlur et al. [30] propose a set of 39 heuristics for "cooperative dashboard design" with the goal of facilitating collaboration between designers and end-users; they stress that a dashboard's quality lies in its ability to promote effective communication and fluid data exploration, going beyond visual aesthetics.

Morroni et al. [31] also reinforce the need for specialized visualization heuristics. They identified the lack of a heuristic set "widely accepted by the visualization community" to evaluate the quality of systems in this area. In response, they proposed a new set of eight heuristics, which were built and validated with the support of InfoVis community members. The work of Morroni et al. inspired our research, as their heuristics embrace aspects of visualization and usability, and the authors demonstrate the process of creating domain-specific heuristics by grouping a large volume of criteria into a reduced set. Their eight heuristics are: Help and error management, Interaction and view transformation, Action Control and feedback, Decreased visual effort, Decreased cognitive effort, Decreased motor effort, Ease of obtaining and deriving information, and Visual mapping. A full description of these heuristics may be found elsewhere [31].

Complementing this perspective, the classic works of Tufte [11], Card et al. [12] and Shneiderman [32] emphasize the importance of graphical integrity, visual clarity, and interactivity as fundamental aspects for visualizations to aid in understanding and reasoning about data, allowing users to see the big picture while simultaneously exploring details of interest.

3) Recommendations for BI tools: In the area of BI evaluation, it is important to note that most of the analyzed works based their methodology on user testing. In these tests, participants were asked to perform specific tasks to identify errors and difficulties. It was found that the proposed improvements tend to rely on more generic usability principles. HEv although an effective technique, was rarely used or was applied with general-purpose heuristics not specific to BI. Magdalena et al. [33] proposed recommendations to improving usability in BI tools based on user tests in a corporate environment, identifying difficulties in task execution. Jooste, Biljon, and Mentz [34] investigated the usability of BI applications in a mining organization and proposed a set of guidelines for evaluating these platforms. This study is relevant to the present research as it validates the premise that generic heuristics need to be customized for BI tools. Smuts, Scholtz, and Calitz [3] focus on the challenges faced by novice users of BI platforms. The authors emphasize that while the field of usability for general-purpose tools has matured, specific criteria for the BI context are still lacking, which hinders effective use by users without technical knowledge. Khanal [35] proposes recommendations for information clarity, a fundamental aspect for data comprehension. Even, Kolodner, and Varshavsky [36] suggested using a Feedback and Recommendation Mechanism (FRM) to improve navigating and exploring in complex data. Gunadham [37] recommends a list of functionalities that BI tools should have to enhance the user experience, based on exploratory tests with real users using commercially available BI tools. Bačić and Fadlalla [38] offer suggestions for the BI field by integrating the areas of visualization and decision-making. The authors proposed a framework that connects the visualization capabilities of BI tools with the dimensions of visual intelligence. By linking the visual elements of BI platforms to the user's ability to extract value from data, Bačić and Fadlalla reinforce the importance of an approach that goes beyond generic usability and impacts the understanding of data analysis. In a current context, Durra and Al-Naymat [39] suggest the integration of artificial intelligence (AI) to enhance decision-making in these tools.

III. METHODOLOGY

This section details the methodological approach used to propose the new set of recommendations to evaluate BI tools. It presents the stages of an exploratory and descriptive approach based on a literature review, with the main objective of identifying and analyzing gaps and proposed improvements in usability and data visualization within BI tools. The purpose is to create a new set of heuristics to complement the HEv process for these platforms. The databases consulted included ACM Digital Library, Springer, IEEE Xplore, Scopus, and Google Scholar. The search strategy used a combination of keywords such as "heuristics", "usability", "data visualization", "information visualization", "Business Intelligence", and "BI tools". The period considered for this search was between 2014 and 2025. The selection criteria focused on works that presented the following:

1) Proposals for improving or identifying usability problems in BI platforms;
2) Proposals for improving or identifying problems in information visualization aspects within BI systems;
3) Studies that applied some form of evaluation, such as heuristic evaluation or user testing, to identify problems in BI tools by collecting feedback on their experiences. Works whose focus fell outside the search delimiters were not directly incorporated, as the focus of this research is on the BI tool itself.

After selecting the papers, our goal was to extract and compile the recommendations, improvements, or guidelines proposed by the authors. We refined and built an initial list of recommendations that addressed both usability and visualization criteria in BI tools. To organize these recommendations and avoid redundancies, we grouped them by similarity of theme and purpose. The final stage consisted of synthesizing the compiled recommendations, subjecting the set of 31 recommendations to an organization and categorization process. This process was guided by the work of Morroni et al. [31], which served as a basis for structuring the improvements. The work of Morroni et al. was chosen as a pillar because it incorporates heuristics for both usability and visualization, which aligns with the objectives of this study.

IV. RESULTS

The data collection stage resulted in the initial identification of 31 articles that aligned with the search criteria. After a more detailed analysis, involving reading abstracts and evaluating the full papers, the sample was refined to a total of 28 relevant works, whose complete list may be accessed on: https://github.com/celmarguimaraes/supplementary_material_for_papers. The analysis of these works revealed a few patterns, such as: 1) The studies were based on user testing. In these tests, participants performed tasks in BI tools with the goal of finding errors and difficulties in carrying out the proposed activities; 2) The most frequently used BI tools were: Microsoft Power BI, Tableau, Qlik Sense, and proprietary enterprise BI analysis tools whose names were not disclosed; 3) Errors were collected and tabulated through questionnaires, interviews, and feedback collection tools; 4) Based on these findings and the existing literature, the authors proposed suggestions or improvements for BI tools. It was observed, however, that most of the recommendations were focused on the usability issues of the tools, while few works presented improvements in the area of visualization. Therefore, the results of this review corroborate the research gap mentioned at the beginning of this paper, namely, the lack of a set of heuristics that integrates both usability and visualization criteria for BI tools.

The suggestions for improvement identified in the 28 analyzed papers were compiled and grouped by similarity, resulting in an initial list of 31 recommendations, some of which were later subdivided. We also discarded some recommendations that were too generic, e.g. “BI tools should facilitate exploration and interaction with data” [38]. At the end of this analysis, we selected a total of 23 recommendations. The next step was the mapping and reorganization of the recommendations found in the literature based on the work of Morroni et al. [31]. It is important to note that the identified recommendations were not incorporated into the heuristics of Morroni et al. at this point; their heuristics served only as a model for organizing the new proposed set. The result of this process is a preliminary set of integrated usability and visualization recommendations, collected from the literature for evaluating the quality of BI tools. This set of recommendations is presented hereafter, organized according to the themes of Morroni et al. heuristics and with references to their source papers.

Help and error management:

1) “The application should make provision for error prevention and recovery. The application should provide help on demand and make provision for user support. Application training should be available (initial training and refresher courses)” [34];
2) “Should provide more teaching material for new users” [37];
3) ”The data should be up-to-date or else users should be notified that the data is out-dated.” [34]

Interaction and view transformation:

1) “The application should limit the memory load. The application should promote learnability to make it accessible for infrequent usage. The terminology used should be familiar to the users” [34];
2) ”BI tools should facilitate exploration and interaction with data. This capability allows users to engage with the data dynamically, which can enhance fluid reasoning and lead to better decision outcomes.” [38];
3) ”The next suggestion is the need for an automatic dashboard update every time users choose, change or cancel parameters without having to press the view or display button first.” [33];
4) “The system should display a hierarchical map to determine data granularity level.” [34];
5) ”Filters applied to data should be highly visible at all times.” [34];
6) “The application should provide a rapid response rate” [34].

Action control and feedback:

1) “We propose to integrate Feedback and Recommendation Mechanism (FRM) capabilities in a manner that would help the end-user navigate through complex data resources and highlight usage directions with a high benefit potential, while still maintaining simple and easy-to-learn functionality. FRM, in the form of visual cues, would provide the end-user with feedback on the analysis done so far, and some guidelines for further actions to consider – e.g., approach certain data subsets and/or apply certain analysis forms.” [36]

Decreased visual effort:

1) "The BI tool should use clear labels, titles, and appropriate chart types ensures viewers can easily understand the information presented." [35].

Decreased cognitive effort:

1) "Learnability should be promoted using familiar terminology, mechanisms for limiting memory loads and provide cues that make the application accessible for infrequent usage." [3];
2) "The application should limit the memory load. The application should promote learnability to make it accessible for infrequent usage. The terminology used should be familiar to the users." [34].

Decreased motor effort:

1) "Software should have better control over total lines in the pivot and model straight tables without the need to download extensions to accomplish this task." [37].
2) "Software should take less time to margin reports and have reusability of existing data to make it easier for coding." [37].

Ease of obtaining and deriving information:

1) "BI tools should integrate advanced statistical and storytelling capabilities. This integration can help users better understand data and translate insights into actionable decisions, particularly in the context of big data." [38];
2) "The integration of advanced artificial intelligence (AI) powered data analysis tools can enhance its effectiveness, leading to greater understanding and a decision-making approach supplemented with comprehensive data." [39].

Visual mapping:

1) "Cube dimensions should be easy to identify, select and view." [34].
2) "Data should be accessible on different levels of aggregation." [34];
3) "We proposed providing variations in graph types will allow the user to gather further insight into the data displayed." [40].

We also found some recommendations that we could not map to Morroni et al. heuristics:

1) "The application should allow knowledge sharing and exporting data. [34];
2) "Users should have the option to save data views on the application." [34].
3) "User application password resets should be automated by the use of email address." [34].

This set of recommendations is a partial result and serves as a basis for the subsequent stages of the research. The next step will be to integrate Morroni et al. heuristics with these recommendations, adjusting the descriptions of the heuristics and adding new ones if necessary. Finally, the intention is to submit the generated set of heuristics to a validation process in order to test its effectiveness and applicability in real-world scenarios of BI tools evaluation.

V. CONCLUSION

In this work, recommendations for improving the quality of BI tools, as presented in the literature in the field, were surveyed and categorized. Eight classes of recommendations were used, based on the respective heuristics of Morroni et al., which incorporate aspects of both visualization quality and usability.

For future work, the heuristics of Morroni et al. will be integrated with the newly proposed set. The next stage will involve validating this new set through tests using BI tools, involving both heuristic evaluations and user testing to compare the results between the two evaluation methods. This process will allow for the refinement of the heuristics, ensuring their applicability and effectiveness in practical scenarios of BI tools evaluation. The creation of a new set of heuristics is expected to offer researchers and professionals a more precise instrument to improve the quality and effectiveness of these systems.

ACKNOWLEDGMENT

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001. We also thank the grant 3446/25 from FAEPEX/PRP/UNICAMP.

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