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Business information visualization intellectual contributions: An integrative framework of visualization capabilities and dimensions of visual intelligence

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ABSTRACT

Modern organizations treat data as an IT infrastructure based upon which business processes and strategy can not only be informed but shaped. One important step in this process deals with the way users consume data through visual display and how those visualization-reliant technologies could impact decision making. Motivated by business information visualization's (BIV) practical relevance and disjointed nature of academic literature, this research summarizes relevant BIV research landscape; by explicating and clarifying visualization terminology and definitions, and condensing relevant literature using a framework that describes and links essential visual elements of business intelligence (BI) platforms to the dimensions of the well-known visual intelligence quotient (IQ) dimensions. The paper identifies gaps and suggests future research opportunities.

1. Introduction

The use of information systems and data to drive business decision making has been one of the defining quests of IS discipline. Ever since organizations began wider adoption of technology for data collection to support business decision making and strategy, a large body of academic research tackled relevant issues of business decision support technologies. These issues ranged from technology, to strategy, optimization, and human–computer interaction perspectives. In the process, many terms have been used, with business intelligence (BI) emerging as an umbrella term for various activities aiming at collecting, storing, processing, and analyzing relevant data to support decision making. Due to, among other developments, advances in technical capabilities, such as storage and processing power, BI's traditional focus on Data Warehousing is being gradually replaced with research and practice focusing more on the "consumption" of collected data. A closer look at business and IT strategy literatures reveals that, from a business impact perspective, our ability to "consume data" is as important, if not more, as efficiency of its collection, processing, and storage. Modern organizations treat data as an IT infrastructure that not only informs but also shapes business processes and strategy. One important and necessary step in this process deals with the way users consume data visually and how visualization-reliant technologies could align with human abilities to support business judgment and decision making.

After decades of investments in IT, many companies feel that achieving business insight and competitiveness through those investments is not nearly as easy as originally hoped [1]. On the other hand, success stories have been documented in research [2] and practice [3]. Not surprisingly, according to a new Gartner survey of more than 2800 CIOs, and for the fourth consecutive year, BI and analytics remain the number one investment priority for CIOs [4]. Proliferation of BI vendors offering and heavily marketing their visual display capabilities through reporting, ad hoc analysis, dashboarding, and visual data discovery, provides evidence of the practical importance of BI's data display to today's modern organizations. Similarly, the academic community over the past few decades identified a number of important aspects and factors of visual data display and its impact on the quality of decision making at, mostly, the user (individual) level. As a result of these efforts, both business information visualization (BIV) practice and research have achieved significant progress, where improvements in system ability to enable conversion of data into actionable insights can be traced to improvements in our understanding and implementation of visual technologies and techniques. At the same time, we are witnessing a cross-disciplinary field with, at times, fragmented knowledge, numerous and sometimes conflicting "best practice principles," and volumes of academic articles that seem to have limited impact on the proliferation of "chartjunk" when designing reports and dashboards in practice. Although BIV garnered great attention in recent times and could be considered one of the most relevant BI topics and "fashions" in the last decade, there has been a dearth of research summarizing disparate literature and contextualizing it into the decision making

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lens. While researchers have widely argued the value of BI [5] and its visual capabilities [6] for improved decision making, they have not equally addressed the possibility that it is through better BI support of users themselves and their human intelligence abilities that better decisions are achieved. Furthermore, little has been done to combine disintegrated literature into a cohesive framework that can provide a more rounded and nuanced understanding of visualization capabilities and help both research and practice in further investigating and deploying those capabilities.

The goal of this research is to bridge these gaps by offering four key contributions. First, consolidation of often overlapping and sometimes disconnected visualization terminologies is provided. Second, in our quest to systematically organize the extensive visualization literature, we adopt and build upon a novel human visual intelligence-based framework [7] for assessing BIV effectiveness. Third, we leverage this framework to identify and internally connect IS literature on data visualization and graphical presentation, as well as externally connect relevant literature from accounting, marketing, human–computer interaction, psychology, cognition, and perception. lastly, BIV research gaps and opportunities are identified.

The rest of the paper is organized as follows. Section 2 provides a summary of relevant terms. Section 3 introduces and discusses the adopted visual intelligence framework. Section 4 provides validation of our adopted framework by aligning relevant literature with the proposed framework. Gaps and future research avenues are identified in Section 5. The paper ends with conclusions and implications.

2. Visualization terminology

A number of terms related to visualization of data are available in the literature, such as visualization (in general), data visualization, information visualization (often called InfoViz by practitioners), scientific visualization, visual analytics, and business visualization (often called BizViz by practitioners). Data visualization emerged in the 1950s with the advent of computer graphics [8] and is defined as the science of visual representation of data. Scientific visualization was used initially to refer to visualization as a part of a process of scientific computing [8] and focuses on processes for steering the data set and seeing the unseen, thereby enriching existing scientific methods [9]. Other variants and subtypes of data and scientific visualization were coined as well and are based on the type of representation they embody (cartographic visualization) or knowledge domain (statistical visualization).

Information visualization has been coined in 1999 as the use of computer-supported interactive visual representations of abstract data to amplify cognition [10]. Typical examples of abstract data that have no inherent mapping to space are employee turnover statistics, bank branch deposit growth data, or sales goals figures. Others suggested that "information visualization utilizes computer graphics and interaction to assist humans in solving problems [11 p.58]" or define it as "…visual representations of the semantics, or meaning, of information. In contrast to scientific visualization, information visualization typically deals with nonnumeric, nonspatial, and high-dimensional data [12 p.12]" or as communication of abstract data through the use of interactive visual interfaces [13].

Visual analytics is the science of analytical reasoning facilitated by interactive visual interface [14]. The initial domain driving the development of this discipline was homeland security but is currently being applied in security, health, commerce, transportation, energy, and personal applications. It is often described as dealing with complex data that enable detection of the expected and discovery of the unexpected [15].

BIV is an incarnation of visualization and is increasingly gaining researchers' and practitioners' attention [9]. While data visualization has been associated to BI from early static charting to interactive charting and dashboarding, BIV has been primarily presented through a representation and interaction lens or a decision making and task-orientation lens. A number of definitions exist for BIV. Tegarden defines it as "simply the use of visualization technologies to visualize business data or information (p.8)". He also recognizes that "…business information has been visualized in the form of tables, outlines, pie charts, line graphs, and bar charts for a very long time. However, today business information visualization means the use of multidimensional graphics to represent business-related data or information [16 p.8]." Zhang offers a more detailed definition of BIV as "a process of creating appropriate computer-generated visual representations of large amounts of non-geometric managerial data for human problem-solving and decision making support [9 p.4]." Card, Mackinlay, and Shneiderman [10] definition could be applied to business context by defining BIV as the use of computer-supported interactive visual representations of abstract *business* data to amplify cognition.

One could discern many similarities and differences among these various definitions. A clear thread among all of the definitions is the computer-supported interactive visualization of data. A temporal dimension can be observed, in that whereas earlier definitions focused on the development of visualization techniques and on the data understanding, the latter definitions focused more on the use of visualization, its impact, and, even, its role in behavioral understanding (for example, in security and business applications). We could offer a more comprehensive definition of BIV as the use of computer-supported interactive visual representations of business data to amplify cognition, achieve better data, business, and behavior understanding to improve decision making and business impact. The advantage of this definition is that it integrates the main features of previous definitions and brings forth the importance of understanding behavior, improving decision making and business impact, and explicitly highlights the importance of linking visualization to human cognition.

3. Organizing framework

In order to organize the substantial business visualization literature, we look at the aim of the underlying technology or phenomenon, in this case BI, as a basis for a literature-organizing framework. A goal of BI is to create "intelligent businesses" by delivering "the right information to the right people" [17] where asking the right questions is the precursor to making intelligent decisions. BI is designed to help individual users wrestle with vast quantities of data as they make decisions about organizational operations and processes. The objective is to improve the timeliness, meaningfulness, and quality of inputs to the decision process [5]. In short, an effective business decision benefits from an effective BI system that enhances users' *abilities* to make better decisions. In this role, visualization is viewed as key by many [18–21]. More specifically, BIV, to effectively assist human intelligence, needs to manifest intelligence in its own design and deployment by supporting and accentuating relevant human intelligence dimensions. This requires software that seamlessly interacts with the brain to support and extend its cognitive abilities.

Struggling with similar issues, prior research [7] initiated a suggestion of formal human intelligence-based lens to BIV-focused BI capabilities. Even though the importance of linking decision support technologies and human intelligence was recognized quite early [22–25], a large body of BI and BIV literature has ignored this link. Yet, anchoring our perspective on the link between technology and human intelligence, and evaluating existing and prospective research through this lens offers a new way to assess the literature. Therefore, this research adopts and expands the human-intelligence-based framework as originally suggested in Bacic and Fadlalla [7]. This framework is based on the best known human intelligence measurement test—Stanford–Binet IQ (intelligence quotient) test and its latest fifth edition (SB5) [26]. SB5 includes the first published testing of nonverbal content which is of special interest to this paper. The Nonverbal IQ (NVIQ) or Visual IQ of SB5 (Fig. 1) measures the general ability to reason, solve problems, visualize, and recall information presented, in