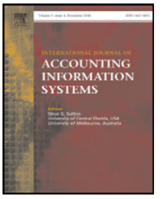
International Journal of Accounting Information Systems 13 (2012) 41–59

Contents lists available at SciVerse ScienceDirect

International Journal of Accounting Information Systems



A review of dashboards in performance management: Implications for design and research

Ogan M. Yigitbasioglu [a,*], Oana Velcu [b,1]

[a] *Queensland University of Technology, 2 George St, Brisbane QLD 4000, Australia*
[b] *Department of Business Technology, Aalto University School of Economics, P.O. Box 21210, FI-00076 Aalto, Finland*

ARTICLE INFO

Article history:
Received 26 March 2010
Received in revised form 1 August 2011
Accepted 4 August 2011

Keywords:
Dashboards
Visualization
Presentation format
Display format
Performance management
Performance measurement
Graphs

ABSTRACT

Dashboards are expected to improve decision making by amplifying cognition and capitalizing on human perceptual capabilities. Hence, interest in dashboards has increased recently, which is also evident from the proliferation of dashboard solution providers in the market. Despite dashboards' popularity, little is known about the extent of their effectiveness, i.e. what types of dashboards work best for different users or tasks. In this paper, we conduct a comprehensive multidisciplinary literature review with an aim to identify the critical issues organizations might need to consider when implementing dashboards. Dashboards are likely to succeed and solve the problems of presentation format and information load when certain visualization principles and features are present (e.g. high data-ink ratio and drill down features). We recommend that dashboards come with some level of flexibility, i.e. allowing users to switch between alternative presentation formats. Also some theory driven guidance through pop-ups and warnings can help users to select an appropriate presentation format. Given the dearth of research on dashboards, we conclude the paper with a research agenda that could guide future studies in this area.

1. Introduction

Due to continuous advancements in Information and Communication Technologies and the fast-paced nature of the business environment today, organizations generate and deal with increasingly more data. Managers are often overwhelmed with reports and information churned out from a multitude of

* Corresponding author. Tel.: +61 7 313 84355; fax: +61 7 3138 1812.
E-mail addresses: ogan.yigitbasioglu@qut.edu.au (O.M. Yigitbasioglu), oana.velcu@aalto.fi (O. Velcu).
[1] Tel.: +358 9 431 38323.

1467-0895/$ – see front matter
doi:10.1016/j.accinf.2011.08.002

organizational information systems such as Enterprise Resource Planning (ERP), performance scorecards, and business intelligence (BI) software that compete for managers' attention. This phenomenon is generally known as information overload. The problem is further exacerbated when reports are poorly designed with respect to how information is presented, which often distract than guide decision makers' attention.

Performance dashboards might offer a remedy to the information overload problem by providing an all-inclusive package for performance management, incorporating various concepts and applications such as strategy maps, scorecards, and BI into one manageable solution. Although promising, a dashboard's value is inextricably linked to its features and the way they are utilized in organizations. However, there is no agreement over how exactly a dashboard should look like and what it should do. Generally speaking, a dashboard is expected to collect, summarize, and present information from multiple sources such as legacy-, ERP, and BI software so that the user can see at once how various performance indicators such as order-fill rates and sales returns are performing. As far as data is concerned, a dashboard represents the tip of an iceberg, i.e. what the user sees at first and if needed, analyses further to uncover causes of poor performance. The software vendor market reflects the lack of consensus over the dashboard concept. Whereas some solutions come with “full” features, i.e. interactive drill down capabilities, scenario (what-if) analysis, built-in automated alerts, customization options, etc., others are more simple and static by nature.

Dashboards have been well received and interest in them is growing. For example, Negash and Gray (2008) regard them as one of the most useful analysis tools in BI. A handful of success stories reported in professional journals on actual dashboard implementations seem to support this claim, i.e. Schulte (2006) found that the use of IBM's Business Objects Dashboard Manager at Edward Hospital improved its cash flow through the better management of account receivables. Also, Unisys' marketing dashboard led to improved budget allocation, accountability, and performance management (Miller and Cioffi, 2004). Whether the purpose is to improve internal control or performance management in the midst of an economic downturn, the ability to access and quickly evaluate different aspects of a company's performance is essential (Hanoa, 2009).

Although dashboards seem to have caught on as a management tool, the scientific literature has failed to keep pace with the developments. While textbooks (e.g. Few, 2006; Rasmussen et al., 2009) and articles in business press (e.g. Miller and Cioffi, 2004; Kawamoto and Mathers, 2007) on dashboards abound, only a handful of studies can be found in academic journals, providing little guidance for practitioners (Pauwels et al., 2009) and researchers. The few scientific studies on dashboards have looked at the motivation (Wind, 2005; Pauwels et al., 2009), implementation stages of dashboards (Pauwels et al., 2009), and selection of metrics (DeBusk et al., 2003; Pauwels et al., 2009), which left the critical issue regarding their design essentially unaddressed. However, there does not seem to be a simple solution to dashboard design. For example, the literature on information presentation format, which dashboards draw on, is in disagreement over the techniques of visual representations that should be used to improve decision making (O'Donnell and David, 2000). There is the view that IS need to be designed according to the types of tasks (e.g. Vessey, 1991; Dilla and Steinbart, 2005), knowledge (e.g. Cardinaels, 2008), and the personality (Boon and Tak, 1991; Kostov and Fukuda 2001) of users. On the other hand, Huber (1983) suggests that decision support systems (DSS) come with flexibility as catering for the different cognitive styles of users is difficult, if not impossible. It is against this backdrop that we believe a review of the current literature that dashboards draw on as well as the development of an agenda for dashboard research could offer value to both practitioners and researchers.

The overall purpose of this paper is to provide a state of the art review of the role of dashboards as decision support tools in performance management and to identify possible design issues that need to be addressed when implementing them. To this end, we begin with the research questions and then present a summary of the previous research that draws on models and theories in human information processing and IS. Finally, we present the implications and future research opportunities in this field.

2. Research Questions

A dashboard can be regarded as a data driven decision support system, which provides information in a particular format to the decision maker. Hence, dashboards need to be evaluated according to their design features and the way the users interact with them to make decisions. Users arrive at decisions through cognitive processes, where information is processed and meaning is derived. The decision process is a function of the information system's features, the decision making environment, and the problem solving skills of the user (O'Donnell and David, 2000). An information system provides symbols and decision cues to the decision maker. Symbols refer to the notational and symbolic representations of physical reality (Haeckel and Nolan, 1993; Sowa, 1997). “A decision cue is a feature of something perceived that is used in the interpretation of perception” (Choo, 2009, p 1074), where perception is an inferential process as objects in the environment can only be perceived indirectly through available information that has been sensed by the individual (Brunswik, 1952). The decision making environment consists of objects representing reality (e.g. people, things, and events) and context (e.g. accountability and group membership), which recognizes differences in the decision environment (O'Donnell and David, 2000). Problem solving skills are shaped by the knowledge and ability of decision makers as well as their perceptions of reality, which are embodied by mental representations in a person's neural space (David et al., 1999). Finally all the variables interact to determine the processing strategy, where meaning is assigned to decision cues and the relative value of each cue is determined to make a decision (Newell and Simon, 1972).

Three of several IS research streams that O'Donnell and David (2000) identify are highly relevant from a dashboard design perspective, i.e. (i) the interaction and feedback given by information systems (ii) the type of presentation format to be used, and (iii) differences in the amount of information load. In the context of dashboards, the level of interactivity is likely to depend on the purpose and features of the dashboard. Feedback might be desirable so as to alert users when performance targets are missed and possible courses of actions are advised. However, there needs to be a balance between the complexity and usability of dashboards, where excessive features and feedback might negatively affect decision making and morale. Dashboard designers also face the problem of presentation format as there are alternative ways of displaying metrics and trends on a dashboard (i.e. tabular information vs. graphs). Finally, information load is an important issue, as dashboards need to provide the right amount of decision cues, without overwhelming the user with excess information. Given the different options, the design of dashboards poses a challenge for companies intending to use them effectively. We therefore seek to answer the following three research questions in this paper, which we address in Section 3.

RQ1: What are the design features of an effective dashboard and is there a general dashboard design strategy that might be suitable to all types of users within organizations?

Unless a one size fits all approach is deployable, organizations need to be aware of the impact of their design choices on the efficiency and effectiveness of decision making. As part of our discussion, we also think that it is imperative to establish the relationship between performance management and visualization which gave rise to dashboards in the first place. Hence, this is taken up in Subsection 3.1.1 as a subtopic to RQ1. Furthermore, we also need to ask the following question.

RQ2: To what extent should users' tasks and knowledge in terms of, for example, education, experience and skills (e.g. IT skills) be taken into account when designing dashboards?

This is in line with the general IS design framework of O'Donnell and David (2000). However, we also consider personality type of the user as a further factor that might need to be taken into account as this has been previously discussed in the information systems literature (Bariff and Lusk, 1977; Liberatore et al., 1989; Carpenter, 1993; Kostov and Fukuda, 2001). Hence this leads to our third research question.

RQ3: Do designers of dashboards need to develop different solutions based on end users' cognitive styles and personality types?

The knowledge obtained from such an investigation could be used to improve the design of dashboards and/or to advocate user training. For example, is it only the younger, less tenured and more technology savvy accountants who are more likely to use dashboards? On the other hand, if the link between user knowledge, skills, personality, and dashboard benefits is weak, which means the concept of fit is irrelevant, then the design of dashboards may not pose such a big challenge.

3. Literature Review

For the literature review, we followed the recommendations of Webster and Watson (2002). We searched papers based on keywords in research databases including ProQuest, Business Source, EBSCO, Emerald, JSTOR, SpringerLink, and Wiley. The keywords that we used were “dashboards,” “visualization,” "presentation format," "display format," "graphs," and "performance management/measurement." We filtered the returned articles according to their relevance to the subject of the paper. We did not limit our search to accounting, AIS or MIS journals because of our multidisciplinary approach. This proved to be beneficial as articles that were published in, for example, marketing and psychology journals provided important insight into the subject. We then reviewed the references (going backward in time) as well as the citations (going forward in time) of the identified publications. We present a summary of the most important findings relevant to dashboards in Table 1. The literature review presented in the next section follows the structure of the table, where we first define and describe the dashboard and then focus on the interaction between tasks, user characteristics and presentation formats from a decision making performance perspective. The numbers in the parentheses refer to Fig. 1, which depicts the different paths that research has followed to date.

3.1. Dashboards: Functional and Visual Design Features

Dashboards became popular after the Enron scandal in 2001 (Few, 2006) but there is not a clear definition of dashboards, neither given by software vendors nor by academics. The dashboard vendors define dashboards from the perspective of characteristics that their products have. Researchers talk about different types of applications of the dashboard concept and different stages in their development (Pauwels et al., 2009). A generic description of dashboards may be that of a graphical user interface that contains measures of business performance to enable managerial decision making. This definition comprises the visual display of the dashboard concept, the content, and the purpose for which dashboards are used. Few (2006, p. 34) defined dashboards in terms of common characteristics of every example of dashboard that he could find on the web: "A dashboard is a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance."

In view of the recent developments in their design, their purpose and the concept itself, a more accurate definition of a dashboard might be that of a visual and interactive performance management tool that displays on a single screen the most important information to achieve one or several individual and/or organizational objectives, allowing the user to identify, explore, and communicate problem areas that need corrective action. This definition emphasizes their interactivity and refines its purpose.

The terminology originates from the vehicle dashboard, which reports the few metrics that the driver needs to know. Dashboards help managers to visually identify trends, patterns and anomalies about business, which makes the issue of visual information design very important. There may be several purposes of a dashboard, i.e. to enable (i) consistency, (ii) monitoring, (iii) planning, and, (iv) communication (Pauwels et al., 2009). Consistency refers to the measures and the measurement procedures used across departments and business units. Monitoring is the day to day evaluation of metrics that should result in corrective action. A dashboard may also be used for planning by allowing the simulation (what if analysis) of various business scenarios in the future. A dashboard does not only communicate performance to stakeholders but also the values of an organization through the choice of the metrics.

We distinguish between two types of design features: functional features and visual features. Functional features are the features that relate indirectly to visualization but describe what the dashboard can do (see Fig. 1). On the other hand, the visual features refer to the principles of visualizing data, i.e. how efficiently and effectively information is presented to the user. It is important that the functional features of the dashboard fit with its purpose(s): a poor fit might result in sub optimum decisions, providing incomplete decision cues and symbols to the decision maker. There will be, for example, a poor fit when a dashboard is intended to be used as a planning tool but when it lacks the functional features to carry out scenario analysis. The dashboard may also be used as a tool to communicate strategy (as in the BSC) but it may not reflect this in terms of how the performance measures are displayed (e.g. the order of measures, display size, etc.). Furthermore, even if there is a fit (i.e. all the required information and features are available to the user), a poor visual design (e.g. excessive use of colours, low data-to-ink ration, etc.) may confuse and distract the user. The issue of visual design is further discussed in the following sections.

Dashboards, as many other visualization tools draw on the principles of visual perception. Visual perception can be explained through the application of Gestalt psychology to visualization. Gestalt

Table 1
Summary of key findings regarding presentation formats and dashboards.

Dashboard definition and purposes (1), visual feat., information load — >Decision Performance (6)	Study
Dashboard definition	Few (2006)
Dashboard purposes	Pauwels et al. (2009)
A dashboard should fit on a single screen but allow data to be drilled down	Few (2006)
The use of Gestalt principles to improve perception	Moore and Fitz (1993)
Use of colours to enhance perception	Goldstein (2007)
High data to ink ratio to maximize attention paid to important information	Tufte (2006)
The introduction of grid lines into 2D and 3D graphs prevents decision bias	Amer and Ravindran (2010)
There is a U relationship between information load and decision accuracy	Shields (1983), Iselin (1988)
Increasing the number of information cues can lead to less consistent decisions	Chewning and Harrell (1990), Stocks and Harrell (1995)
Altering the display format can help focus on more relevant information	Dilla and Steinbart (2005)
Supplementing BSC's with strategy maps increased attention paid to KPI's	Banker et al. (2004)
Performance markers (e.g. +/−) can help eliminate bias in connection to BSC presentation format	Cardinaels and van Veen-Dirks (2010)
User tasks, knowledge and presentation format —>decision Performance (2+5) (3+5)	**Study**
Tabular information was superior to graphs with respect to consensus among decision makers. Task difficulty not affected by supplementary BSC information	Dilla and Steinbart (2005)
Tabular information more suitable for symbolic tasks: e.g. for extracting specific values and combining them to an overall judgement	Vessey (1991), Umanath and Vessey (1994)
Tabular information led to better decisions involving selective tasks (monitoring specific values)	Amer (1991)
Tabular information was found to be more superior when tasks became more complex and information cues became less consistent	Davis (1989a, 1989b), Liberatore et al. (1989), Blocker et al. (1986), So and Smith (2004)
Tabular information led to more accurate decisions for accumulation tasks	Hard and Vanecek (1991)
Presentation format did not affect value judgements of auditors	Kaplan (1988), Bricker and Nehmer (1995), Frownfelter-Lohrke (1998)
Sales forecasts based on tabular format were more accurate than graphical animations	Hasbun (2009)
No one form of presentation is best in all situations.	Davis (1989a, 1989b)
Graphs are more suitable for spatial tasks: e.g. for comparing a set of values.	Vessey (1991) Umanath and Vessey (1994), Vessey and Galletta (1991)
Graphs reduced the negative influence of information overload	Diamond and Lerch (1992), Umanath and Vessey (1994)
Graphs led to more accurate financial predictions	Hard and Vanecek (1991)
Graphs were found to be superior for correlation and sales forecasting tasks but value added decreased with auditing experience	Anderson and Mueller (2005)
Broad scope information (less aggregate) appeared to be more beneficial in marketing, where marketing was assumed to have a higher level of uncertainty than production	Mia and Chenhall (1994)
Graphs produced better correlation estimates and decreased time on task	Schulz and Booth (1995)
Graphs improved accuracy of bankruptcy, earnings, and sales forecasts	MacKay and Villarreal (1987), DeSanctis and Jarvenpaa (1989), Anderson et al. (1992), Anderson and Reckers (1992)
Graphs led to higher accuracy for complex auditing tasks	Wright (1995)
Graphs produced better performance evaluations that required holistic decision strategies	Tuttle and Kershaw (1998)

(continued on next page)

Table 1 (*continued*)

Users who chose preferred presentation format made more accurate decisions for symbolic tasks	Wilson and Zigurs (1999)
Self organizing maps and multidimensional scaling did not significantly outperform tabular representations.	Huang et al. (2006)
Schematic faces and bar chart graphs produced superior performance to financial ration and trend diagrams	So and Smith (2003)
Geographical information systems do not ensure superior performance over tabular information	Dennis and Carte (1998)
Higher task uncertainty requires more disaggregate data	Benbasat and Dexter (1979)
Users with low level of accounting knowledge made better decisions with graphs. Users with high level of accounting knowledge made better decisions with tables	Cardinaels (2008)
Personality type and presentation format —>decision performance (4 + 5)	Study
Personality type did not affect the value perceived from different presentation formats	Liberatore et al. (1989) and Carpenter et al. (1993)
Customization of user interfaces to match personality type may lead to success	Boon and Tak (1991)
Users performed better when they handled an interface that matched their personality type	Kostov and Fukuda (2001)
Cognitive styles (MBTI) and field independence had no impact on decision quality with varying presentation formats	So and Smith (2003)
Decision support systems should not be designed according to the desires of individual managers	Vessey and Galletta (1991)
Low analytics with disaggregate data performed better than low analytics with structured and aggregate data	Benbasat and Dexter (1979) Bariff and Lusk (1977)
Analytic planners performed more confidently with less aggregate data. Heuristic planners performed equally well with aggregate and less aggregate data	Lederer and Smith (1988)

psychology was born in reaction to atomism at the end of the 19th century with the view of things “as more than the sum of their parts.” The Gestalt psychologists were intrigued by the way our minds perceive wholes out of incomplete elements (Behrens, 1984; Mullet and Sano, 1995). Among the Gestalt principles that dashboards use are proximity, similarity, continuity, figure-ground, symmetry, and the closure of objects (Moore and Fitz, 1993).

Dashboards convey information through visualization, where information visualization refers to the “use of interactive visual representations of abstract, nonphysically based data to amplify cognition” (Card et al., 1999). The process of visualization involves two distinct phases: encoding and decoding. They are facilitated through the use of visual attributes such as shape, position and colour, and textual attributes such as text and symbols, which themselves are represented with simple visual attributes (Wunsche, 2004). Visualization is effective if the decoding is done “correctly,” where perceived data quantities and relationships between data reflect the actual data. Visualization is efficient if the maximum amount of data is perceived in a minimum amount of time. According to Friedman (1979) and Olivia (2005), visual perception involves two elements: the perceptual and conceptual gist. The perceptual gist refers to the process of the brain when it determines the image properties that provide the structural representation of a scene, like colour and texture. The conceptual gist refers to the meaning of the scene, which is improved after the perceptual information is received.

Dashboards can be evaluated according to how well they facilitate the encoding and decoding of information. A good balance between visual complexity and information utility is required. Visual complexity refers to “the degree of difficulty in providing a verbal description of an image” (Heaps and Handel, 1999; Oliva et al., 2004). Visual complexity might increase with the quantity and range of objects as well as with varying material and surface styles (Heylighen, 1997). Conversely, repetitive and uniform patterns and existing knowledge of the objects in the scene reduce visual complexity (Oliva et al., 2004).

Dashboards often make use of colours to discriminate objects from one another or to recognize and identify them (Goldstein, 2007). Although the use of colours may improve the process of visualization,

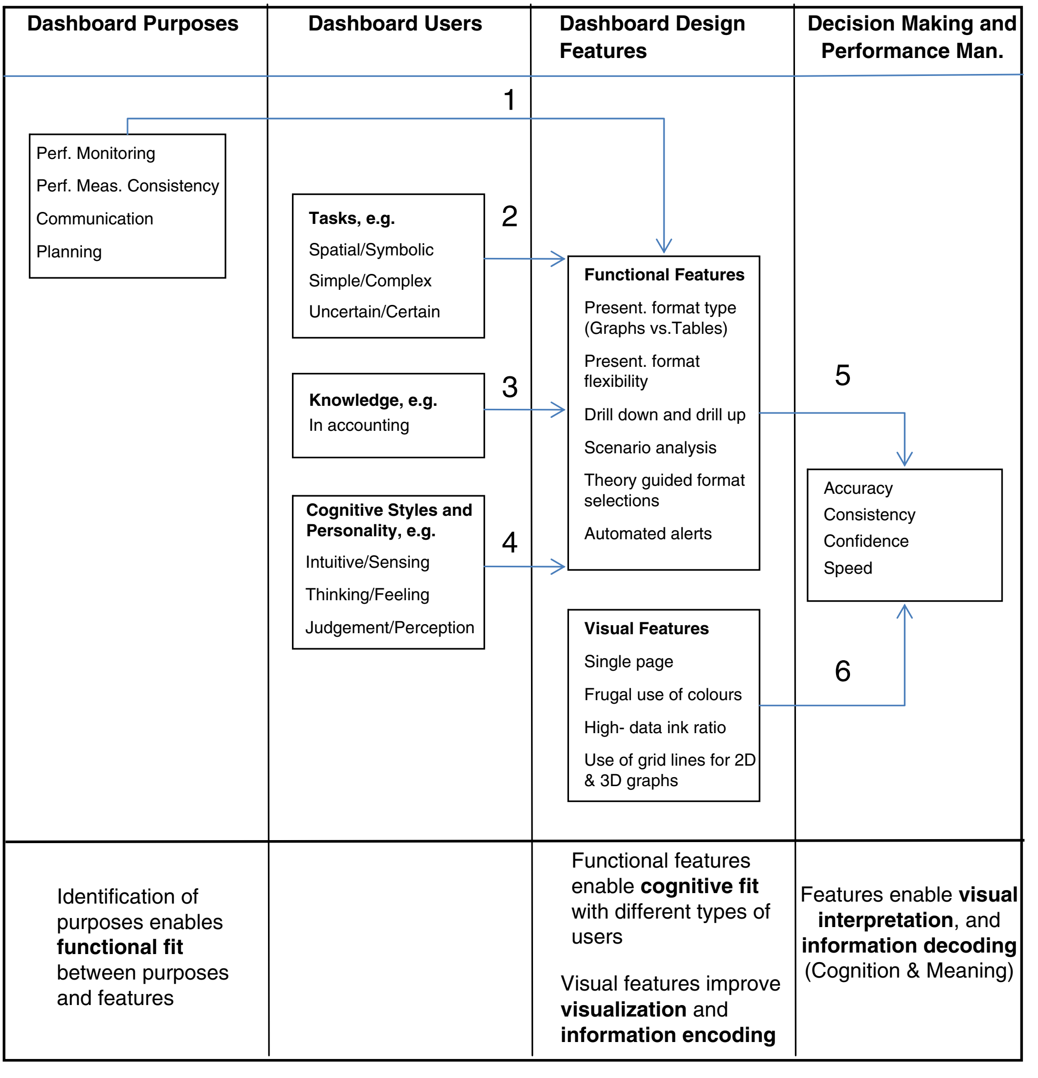


Fig. 1. A summary of dashboard research paths with implications on design.

excessive use of colours can distract the user and may therefore have an adverse effect on decision making. Similarly, redundant visual information in graphs such as decorated frames and non value adding 3D objects could limit attention paid to important information. To remedy this problem, it has been suggested to maximize the data-ink ratio, which measures the proportion of ink used to represent data to the total ink used to print the graph (Tufte, 2006). Furthermore, some 2D and 3D graphs can cause visual illusions (Poggendorff illusion) that bias decision making. To solve this problem, Amer (2005) and Amer and Ravindran (2010) suggested the use of gridlines as visual aids. Other guidelines for presenting graphical information can be found in for example, Tufte (1983), Jarvenpaa and Dickson (1988), and Wainer (1997).

Although it is strongly suggested that a dashboard fit on a single computer screen, the information displayed on dashboard should open the door to additional information (Few, 2006). Thus, some of the newer generation dashboards include point and click interactivity that allow users to drill down information (dimensional analysis) so as to obtain further details on various performance measures. Furthermore, dashboards can also help users to identify measures that need immediate attention by visually alerting (trough bright colours and/or flashing) the user when performance indicators go out of range.

Overall, the requirements of new generation dashboards refer to (1) aligning business processes with latest information to provide business intelligence at all levels in the company, (2) using intuitive and easy to digest visuals for delivering information to busy executives, and (3) sound navigation (Ziff Davis Enterprise, 2008). The last two requirements highlight the importance of dashboards to provide data visualization in a way that makes sense to the individual. This can be achieved through design elements such as the frugal use of colours, high-data ink ratio and the use of gridlines in graphs, as well as drill down capabilities from the single dashboard page. Thus, if designed properly, dashboards can offer the solution to information overload or miscommunication regarding reporting in companies. In the next section, we provide a brief analysis on the link between performance management and the use of visual aids, which led to the development of dashboards.

3.1.1. Towards Visualization in Performance Management

Dashboards have their application in organizational performance measurement and management. Performance measurement is an established concept. Performance measurement systems provide the means of monitoring and maintaining organisational control whereby the achievement of goals and objectives of an organization are ensured (Nani et al., 1990). Thus, “measurement provides the basis for an organisation to assess how well it is progressing towards its predetermined objectives, helps to identify areas of strength and weaknesses, and decides on future initiatives, with the goal of improving organizational performance” (Amaratunga and Baldry, 2002, p. 217).

Traditionally, performance measurement was primarily based on accounting information such as summary measures (e.g. net income, operating profit) and ratios (e.g. ROI, ROE) (Merchant and Van der Stede, 2007). A turning point in the area of performance measurement occurred when Kaplan and Norton (1992) published their seminal paper titled “The Balanced Scorecard”. Kaplan and Norton (1992) suggested the use of both financial and non-financial measures in performance measurement. Thus, the Balanced Scorecard concept (BSC) (Kaplan and Norton, 1992, 1996) has become the best-known attempt to broaden performance measurement by including non-financial measures (relating to learning and growth, processes, and customers) aside from conventional accounting information. Typically, a BSC includes more than 20 individual measures (4–7 measures in each dimension), which then make up the holistic performance rating of an organization (Neumann et al., 2008).

However, there is little guidance as to how and to what extent non-financial measures should be used (Corona, 2009). According to Ittner and Larcker (2003), executives assign either equal weights to non financial measures, go with fashion or rely on their own assumptions about the measures' strategic importance. Furthermore, Ittner and Larcker (2003) provide evidence that corporate managers routinely discount or ignore non-financial measures. One explanation for such behaviour could be the subconscious limitation to information processing because decision makers can only process a fraction of the available information (Neumann et al., 2008). Decision-makers are symbol manipulation systems that process information by structuring problem spaces and searching those spaces until a goal is achieved. The space search is limited by the human's limited span of attention (e.g. the number of symbol structures to which a human can attend simultaneously) (Newell and Simon, 1972). In line with the information processing theory, for example, Neumann et al. (2008) suggested that evaluators' judgements could be traced to less than 4 measures, which agrees with Halford et al. (2005). Hence, given that individuals have limited working memory store, they should rationally focus on information with increased likelihood of diagnostic capability. The order and categorization (e.g. financial vs. non financial) of the information presented to the users is also relevant. For example, decision makers when presented with information in the BSC format assign more weights to financial measures where this can be corrected using performance markers (e.g. +, −) (Cardinaels and van Veen-Dirks, 2010).

Excessive information may not only lead to disregard of information but also to decision inaccuracy. Shields (1983) and Iselin (1988) found an inverted U-relationship between the accuracy of decision-making and the quantity of information supplied. The inverted-U relationship indicates that there is a certain level of accounting information supplied in reports that results in the most accurate decisions. More or less information decreases the decision accuracy. Furthermore, more information could lead to less consistent decisions (Chewning and Harrell, 1990; Stocks and Harrell, 1995).

To overcome the abovementioned problems regarding complex judgement tasks, Silver (1990, 1991) suggested supplementing or altering the way information is displayed. This kind of informative guidance (visualization) can help facilitate better decision making by making it easier to focus on the relevant portion of the information set (Dilla and Steinbart, 2005). Thus, Banker et al. (2004) found that BSCs supplemented with strategy maps that show the linkages between performance measures and the different aspects of an organization's strategy increases attention paid to those measures when evaluating divisional performance.

Thus, an initial review of the literature in performance management indicates that information visualization can potentially improve cognition as it helps to digest complex information more efficiently. However, structuring and data aggregation, which is especially relevant to dashboards is to be done with caution as this may not always produce the best results. For example, tasks that are more uncertain may require relatively more detailed data (Benbasat and Dexter, 1979; Mia and Chenhall, 1994). Also, the cognitive skills of users (e.g. analytical versus less analytical) affect the demand for aggregate data (Lederer and Smith, 1988). Such findings point on the need to bear in mind users' tasks and knowledge/skills when designing dashboards and reports in general, which is the topic of the following sections.

3.2. User Tasks, Knowledge and Presentation Format

The use of graphs to report accounting information has been studied from different angles. For example, Beattie and Jones (2000) pointed to a reporting bias in financial graphs in corporate annual reports, which were used to make a favourable impression on the readers. Thus, Raschke and Steinbart (2008) proposed user training for mitigating the effects of misleading graphs on decision makers. Within the context of management accounting, researchers attempted to show that graphs could lead to superior decision-making performance compared to tables (Vessey, 1991). However, Vessey and Galletta (1991) concluded that there is no agreement over which types of presentation format (i.e. table or graph) is better.

Research on information display suggests that for example, the use of tables versus graphs depend on the nature of the task. Based on human information processing (HIP) theory, Vessey (1991) introduced the cognitive fit theory that explains under what circumstances one mode of information presentation outperforms the other. One underlying principle of this theory is that graphical and tabular representations present the same type of information but in fundamentally different ways: graphical representations are spatial information and tabular representations are symbolic information. Tasks can also be divided into spatial and symbolic tasks. According to cognitive fit theory, graphs are more useful for tasks that require identifying and understanding relationships and for making comparisons (i.e. spatial tasks), while tables are better for tasks that require extracting specific values and combining them into an overall judgement (i.e. symbolic tasks) (Vessey, 1991; Vessey and Galletta, 1991; Umanath and Vessey, 1994).

According to Dilla and Steinbart (2005), judgement quality is affected by the display format. Judgement quality is a function of consistency (within an individual's own decisions) and consensus (among individuals' decisions). The two quality measures are considered important so as to ensure an objective and fair outcome of the performance evaluation (Malina and Selto, 2001). Dilla and Steinbart (2005) reported mixed results regarding the absolute benefit of supplementary information (tabular versus graphic) in the BSC. However, there was unambiguous evidence that tabular information was superior to the same information displayed in graphical format due to the adverse effect of graphical information on consensus (Dilla and Steinbart, 2005). Nevertheless, other studies, with the exception of Hasbun (2009) did find evidence for graphical presentations to improve the accuracy of spatial tasks such as bankruptcy forecasts, earnings forecasts, and sales forecasts (MacKay and Villarreal, 1987; DeSanctis and Jarvenpaa, 1989; Anderson et al., 1992; Anderson and Mueller, 2005).

Other studies reported that the influence of presentation formats interacts with the characteristics of the decision environment and the knowledge of the decision maker. For example, tabular formats were found to be superior to graphical formats as the complexity of the tasks increased (Blocker et al., 1986; Davis, 1989a, 1989b; Liberatore et al., 1989; So and Smith, 2004). Also, users with relatively more uncertain tasks required more disaggregate information (Benbasat and Dexter, 1979). Furthermore, decision makers with a low level of accounting knowledge made decisions that led to higher profits when they used customer profitability reports, which were presented in graphical format compared to tabular format (Cardinaels, 2008). A surprising result was that the same customer profitability report presented as graphs (versus tables) had a negative effect on profits for users with high levels of cost knowledge. On one hand, these findings emphasize that in order to enable effective decision-making, the data may need to be presented in different presentation formats, i.e. according to the level of accounting knowledge of the user. On the other hand, scholars such as Vessey and Galletta (1991) suggest that providing decision support systems to satisfy individual managers' desires will not have an effect on the performance of decision-making.

Studies have also explored the impact of more advanced presentation formats on decision performance. For example, Huang et al. (2006) tested the cognitive fit theory in the context of expertise management systems by studying the potential of using self-organizing maps (SOM) and multidimensional scaling (MDS) to support more efficient and effective exploration of the information space. The results showed that visual representations of data generated by SOM and MDS outperformed tabular representations for four out of the five low-level spatial tasks (e.g. compare, cluster, rank, and trace). Other studies focused on schematic faces (So and Smith, 2003), geographical information systems (Dennis and Carte, 1998), treemaps (Asahi et al., 1995), and probability maps (Roy and Lerch, 1996), which are recommended for more complex and multidimensional data. However, there was little evidence that the use of such tools affected decision performance.

In the light of the mixed evidence regarding the benefits of one presentation format over the other, Wilson and Zigurs (1999) tested whether individual preference to select among alternative displays had an effect on performance. The results showed no difference among the subjects that could select the display format in comparison to the group that was given a random format in terms of task performance. However, the group that received theory-based format recommendation (based on cognitive fit theory) performed better than the other two groups.

Cognitive fit theory does provide some useful guidelines with regard to the choice of presentation formats to be used, i.e. graphs are well suited for spatial tasks that involve forecasting and comparisons as well as for tasks that require multidimensional data analysis and pattern recognition. On the other hand, tables seem to suit better more advanced users that are more numerical (e.g. accountants and financial analysts). Graphs might also introduce some degree of subjectivity (hence the lack of consensus) if they are not well designed and/or labelled. This might explain some of the contradictions or lack of support in past research for cognitive fit theory. This area offers potential for more research, which is addressed under Section 5 on Directions for Future Research.

3.3. Cognitive Styles, Personality and Presentation Format

Cognitive fit theory is not limited to matching information presentation and task. Vessey and Galletta (1991) introduced an extension to the basic concept of cognitive fit, which includes the fit between an individual's decision-making skills, the information presentation format, and the task. Effective decision making requires users to develop appropriate mental representations, where the mental processes that decision makers use provide the link between representation and task. However, users' mental processes may vary from person to person, depending on his/her cognitive style. This extension could have implications for the designers of decision support systems as they might need to focus on the personality traits of decision-makers along with the tasks they perform. Hence, this section explores the interaction between users personality and decision making performance.

Personality theories have been extensively applied in different research fields but only scarcely in accounting. Wheeler (2001) examined Jungian personality theory and Myers-Briggs Type Indicator (MBTI) to illustrate those aspects of personality that are more relevant to accounting research and education. MBTI instrument is built on Jungian theory of personality. Jung's theory states that a person's personality consists of the interaction between the way of perceiving (intuition or sensing) and the way of judging (thinking or feeling). The Jungian psychology focuses on conscious aspects of personality, decision making, and the effect of personality on understanding. Intuitive persons are more creative and insightful during decision-making processes, whereas sensing individuals prefer to gather data from facts and observations. Thinking individuals are logical and rational whereas feeling individuals are more idealistic.

According to Myers–Briggs Type Indicator (MBTI), there are 16 personality types that can be characterized by occupational and organizational traits, educational traits and learning styles, and decision-making traits and cognitive styles. In each person, there is an innate inclination towards one of the four traits, but the non-preferred traits are present too and the individual can be competent using them.

The accounting research that used MBTI covered mainly two topics: (1) personality types of accounting professionals and (2) correlations between the personality types of accounting professionals and performance. The results point to differences in the personality types of accountants within the various specialities of the profession. For example, an extrovert attitude is more likely to be found in national companies than in local companies. In addition, Chenhall and Morris (1991) and Vaassen et al. (1993) found significant relationships between the MBTI preferences and decision making and cognitive style in practising accountants. Middle and senior level managers with an intuition preference included opportunity cost information in resource allocation decisions, whereas managers with a sensing preference ignored opportunity cost (Chenhall and Morris, 1991). According to Vaassen et al. (1993), auditors have a significantly higher preference for the sensing type of information acquisition. Furthermore, the subjects with thinking preferences accessed more information and took more time to process the information accessed.

Findings on personality type of accountants are consistent with the sensing and thinking preference. This personality preference applies to individuals working in management and administration whose general personal characteristics are practical, sensible, decisive, logical, detached, observant, active, and rational problem solver (Myers, 1998 as quoted in Wheeler, 2001). There is therefore a relationship between the personality type and the role of individuals in organizations.

Information systems researchers used MBTI to measure the relationship between personality and information systems use (Bowen et al., 2003), as well as other measures such as the Witkin Embedded Figures Test (Witkin et al., 1962) or the Bieri Cognitive Complexity Test (Bieri, 1971). Boon and Tak (1991) suggested that the customization of interfaces to match personality types may lead to successful use of information systems. However, Liberatore et al. (1989) and Carpenter et al. (1993) found that personality type had no relationship to a person's perception of the value of different data presentation formats. Also a study by So and Smith (2003) reported that cognitive styles in terms of MBTI and field independence had no impact on decision quality with varying presentation formats. As for data aggregation, there is evidence that some personality types such as low analytics (field dependent) might perform better with disaggregate data than with structured and aggregate information (Bariff and Lusk, 1977; Benbasat and Dexter, 1979).

Although, early research (Bariff and Lusk, 1977; Boon and Tak, 1991) did provide some potential for personality research, the personality type literature with respect to information systems design seems to have lost its momentum. Currently, it does not offer strong evidence for designing reports or dashboards that match users' personality type. Furthermore, it is not clear whether this area can offer research potential. We address this issue under Section 5 on Directions for Future Research.

4. Summary and Implications for Practitioners

Having reviewed the relevant literature on visualization, presentation formats and user characteristics in a decision support system context, we make the following observations and suggestions for designing dashboards.

Dashboards have come a long way: From merely simple standalone displays of KPI's (using personal productivity software) that resembled vehicle dashboards, to interactive enterprise wide decision support systems (built on top of ERPS, BI applications, etc.) that allow drill-downs and scenario analysis. This may not be the end and more functional features can be expected in the future. For example, dashboards may be combined with workflow management systems (WFMS) that could advise users among possible courses of actions based on decision tree rules when targets go out of bounds. However, before adding new features, we suggest to first improve on the existing dashboard solutions by better understanding the features that make them successful. Fig. 1 below presents a summary of the most important findings from the literature review, at the same time highlighting the various research paths and conceptual relationships that we found in the literature. Note that Paths 2, 3, and 4 have looked at the interplay of different user characteristics and report features, which affects decision making effectiveness (Path 5), whereas Path 6 looked directly at visual features and decision making. As for Path 1, we did not identify any research that tested the extent functional fit between the purpose and the features of a dashboard is achieved and how it affects decision making $(1+5)$. Furthermore, there is no path between dashboard user dimensions and visual features, firstly because no research was found in this respect but also because we consider the given features to be universal for every type of user, task, and personality.

The features of dashboards need to be in line with their purpose(s) as shown in Fig. 1 so that functional fit is attained. Whereas, drill down and presentation flexibility as functional features could serve all of a dashboard's purposes (consistency, monitoring, etc.), for example, scenario analysis is only required when it is intended to be used as a planning tool. Unnecessary features add complexity to the dashboard and may impair cognition, whereas too few features will compromise its goals. However, a fit might be a difficult thing to achieve as the exact goal(s) of dashboards might not be always known upfront by the implementing organizations due to fashion and fad motives. Thus, it might be a good strategy to go with dashboard solutions that are more flexible and allow for easy upgrades.

With respect to the fit of the functional design features with user characteristics, dashboard designers might need to bear in mind some of the important findings from the literature, for example, that users might sometimes prefer raw data as opposed to structured and aggregate data. A lack of one or several features can result in a dashboard that is not appropriate for the user. For example, a dashboard without the drill down feature might force an accountant with high analytical abilities and strong IT skills to work with aggregate data that is insufficient, forcing him/her to seek for granular data elsewhere. Hence, the drill down feature emerges as a critical component in a dashboard data, where in its absence, users might be forced to switch back and forth between various applications, which might disrupt the decision making process. Fortunately, some dashboard solution providers already incorporate this feature. As a matter of fact, we suggest dashboards to be fully integrated with the Online Analytical Processing system or data warehouse of an organization, so as to allow users to have full access to granular data for dimensional analysis.

According to cognitive fit theory, tasks that require comparisons (spatial tasks) are better supported with graphs. Since a dashboards' primary purpose is to display and compare KPI's, the use of graphs (including dials) by default seems to be warranted. However, users should have the option to switch to an alternative display format, i.e. to tabular format, in case this is preferred. For different user backgrounds and personality types (e.g. an accountant with high analytical skills), a similar strategy as above could be implemented.

An alternative approach to designing dashboards could be to let the system choose how data is presented to the user instead of building in flexibility. As mentioned previously, Wilson and Zigurs (1999) found an improvement in decision making performance when a guided assignment of the presentation format (spatial vs. symbolic tasks) was made instead of allowing users to select the preferred format. Similarly, the study of Helfman and Goldberg (2007) suggested that the selection of appropriate display formats for users to be based on certain rules, i.e. whether the data are categorical or quantitative, whether the tasks are about comparison or identification of trends or totals, and whether the end users are experts or casual users of graphs. Additional rules could be incorporated taking into account the personality type of users and/or roles. This can be achieved by asking the users directly, i.e. through some sort of pop-ups/warnings and/or through software agents that act on behalf of the user based on past settings and actions. However, it should be noted that not all users may prefer decisional guidance, especially when this limits the user's options (Wilson and Zigurs, 1999).

Also, we suggest incorporating all of the visual features in Fig. 1 so as to maximise visual perception. Thus, the use of colours and the design of graphs should be done according to the principles of visualization, where the goal should be to improve and not complicate, hinder, or bias perception. So, dashboard designers might need to reconsider their choices for flashy graphs and instead go for simple solutions that correctly guide users.

In line with the initial idea, dashboards should continue to be concise, simple, and intuitive to use. This will allow decision makers to focus on the most relevant and urgent part of the data. Hence, we agree with Few (2006) and recommend that dashboards fit on a single page/screen. However, if in line with the purpose, a desirable feature might be to allow users to “zoom out” from their individual dashboards to get a bird's eye view on the corporate dashboard (e.g. in the form of a strategy map). This way, users can see their (department's) relation and contribution to the strategy and value of the company.

In the current economic climate, Business Intelligence (BI) software may help companies to stay competitive by giving a complete overview of critical information at all times. In essence, BI software provides managers with logical connections between cause and effects within a company's figures so that the issues can be proactively tackled. If dashboards are the technology that makes explicit the connections between causes and effects in company's figures, we can assume that the management becomes more aware of what the drivers of profit growth are. Hence dashboards can improve decision making and ultimately company performance, although additional empirical evidence beyond Schulte (2006) and Miller and Cioffi (2004) are needed to back up this claim.

However, there may be also some downsides to dashboards as they could introduce dysfunctional effects. For example, Hunton et al. (2010) reports on the status quo effect (Tetlock and Boettger, 1994) when managers are monitored continuously by their supervisors. The same effect could be observed with dashboards since they can be used as a tool for facilitating continuous monitoring. To remedy the dysfunctional effect due to increased accountability, companies are suggested to consider training (Tetlock and Boettger, 1994) and switching from outcome to procedural (Seigel-Jacobs and Yates, 1996) based evaluation. As we mentioned before, the integration of the dashboard with a WFMS might be well suited for such a task.

5. Directions for Future Research

Surprisingly, there is very little research on many aspects of dashboards and it is not known to what extent they live up to their “promises”. Hence research is needed to advance our knowledge on how they are built in practice (functional and visual features), whether they are effectively utilized, and what impact they have on decision making and performance management. We present below several research streams that future researchers can follow, which we believe could provide the needed body of knowledge in this under researched field. Each of the identified research streams can potentially improve dashboard productivity. As a general proposition, some explorative case studies and surveys that report on dashboard experiences and adoption rates could prove to be useful in order to build a foundation for more theory driven research in the future.

5.1. Dashboard Functional Fit

An area to focus on could be the purposes (e.g. to monitor, communicate or both?) for which organizations use dashboards and how different purposes affect decision making and performance management (Path 1 + 5). This has not been researched before and hence a model could be tested with empirical data, exploring possible relationships between dashboard utilization and outcome measures such as user productivity or performance management improvements. Knowledge gained from such an investigation could be used to encourage their usage in the most productive way, leading to higher return on investments. The measurement instrument developed by Doll and Torkzadeh (1998) that captures information systems usage and purposes, which was subsequently used by Wieresma (2009) in the BSC context, could provide researchers with some of the needed constructs for such a study. Also, a multi item scale could be used to measure user productivity gains or performance management improvements such as decision making accuracy, consistency, confidence and speed, although, some of the benefits are likely to depend on the features and diffusion of the dashboard. For example, little benefit will materialize regarding consensus among employees if the dashboard is only available to a few.

Pauwels et al. (2009) refer to five development stages in dashboards implementations, where in the most advanced stage the measures are linked to strategy and users can make forecasts. Thus, depending on the features of the dashboards, we expect the benefits to vary. Research could identify and rank the features that most strongly correlate with decision making effectiveness.

5.2. Cognitive Fit with User Tasks and Knowledge

A further area for research could be in relation to how much the dashboards used in companies facilitate cognitive fit with respect to user tasks and knowledge (Paths 2 + 5 and 3 + 5). A low fit would have a negative impact on decision making and the benefits obtained from the dashboard. Case studies could provide insight into dashboard development projects and the extent to which the needs of its users are incorporated. Also, how much customization do dashboards allow and what support do end users get?

Since empirical evidence on cognitive fit theory is fairly limited and inconsistent, we see the value in both, exploratory and confirmatory research in this area. Studies are needed to test the link between different types of tasks, presentation format, and decision making performance (rather than user preferences). Moderators and other previously untested variables such as experience might also need to be taken into account. For example, we only found one study that looked into users' knowledge, i.e. knowledge of cost accounting (Cardinaels, 2008). Further studies might shed light on how different types of knowledge and skills (e.g. IT) affect decision making performance. This would allow for a better mapping of the types of tasks to be performed to the presentation format to be used.

5.3. Cognitive Fit with User Personality

The literature review shows that research regarding the link between personality types and information system design requirements made little progress in the past (Path 4 + 5). Although, building in flexibility into dashboards can provide a temporary solution, more research could give better theory driven guidelines to designers of dashboards and decision support systems. This could then enable automatic customization of user interfaces and presentation formats at run time. Despite the potential value, we also acknowledge the difficulties in undertaking such an endeavour. For example, a very large data set may be required given the 16 MBTI dimensions, although some of the dimension (e.g. introvert and extrovert) might not be that relevant. Researchers have also used other constructs for measuring cognitive styles, e.g. the Witkin Embedded Figures Test (Witkin et al., 1962) or the Bieri Cognitive Complexity Test (Bieri, 1971) derivatives that may offer fewer dimensions. Bariff and Lusk (1977) provide an example for the use of the above-mentioned measures in this context, although the measures were only correlated to user preferences and not decision making effectiveness.

Aside from theories like the diffusion of innovation (Rogers, 1983) and the Technology Acceptance Model (Davis, 1989a, 1989b) and derivatives, personality traits may also be used to explore how 'open minded' users are with respect to using a new technology such as the dashboard. For example scales like the Defense Mechanism Inventory (Gleser and Ihilevich, 1969) and Manifest Anxiety (Taylor, 1953) can be used to identify how factors such as resistance to technology and stress levels affect decision making. These findings could then be used to identify users that need additional training and counselling.

5.4. Research on New Dashboard Design Features

As dashboards like any other technology are evolving, we can expect additional features and variations in the future (Paths 5 and 6). We mentioned, for example, the zoom in and zoom out function (linking measures with the overall strategy) or the possibility to integrate dashboards with WFMS so that when a problem is identified, it can guide the user step by step with the decision at hand. This enhanced dashboard (decision management and support system) would make suggestions and keep track of the decisions/actions taken (through i.e. filling in mandatory fields), which could provide an audit trail for ex-post scrutiny. Furthermore, collaborative dashboards could allow online information sharing with colleagues and supervisors on difficult and non routine-decisions, optimizing decision outcomes and concurrently forming a repository for organizational knowledge. This would facilitate knowledge reuse, which has been found to enhance competitiveness in organizations (Argote et al., 2003). Prototypes and proof of concepts are needed to see how these new features can add value to the users and whether these concepts are feasible. Researchers should evaluate the new artifacts according to Hevner et al.'s (2004) criteria. As mentioned before, empirical research based on case studies and surveys on actual dashboard implementations could be fruitful as they might reveal design flaws that are hindering their success.

5.5. Organizational Factors

Dashboards as many other technological innovations may be subject to organizational barriers, which might hinder their adoption and success. As a starting point, the technology–organization–environment framework could be useful as a lens (Tornatzky and Fleischer, 1990). For example, the lack of top management support might be one of the barriers, which is also needed to align business with IT (Reich and Benbasat, 1996). Dashboards may also be viewed as a competing tool rather than as an enhancement on the existing management control tools in an organization (e.g. legacy system reports, BSC). This would hinder their approval from management, which would translate into a missed opportunity. For example, the management control tightness (Merchant and Van der Stede, 2007) of a company might affect dashboard use, i.e. it has been suggested that the use of action, personnel, and cultural controls might substitute (Eisenhardt, 1985; Banker et al., 1996) or complement (Jensen and Meckling, 1992) the use of results driven management control tools such as the dashboard. For example, Wieresma (2009) found that increased action controls led to an increased usage of BSC for decision making and rationalizing. An explanation given by Wieresma (2009) is that action controls make managers more accountable, which might require employees to more often explain to their superiors why they took a certain decision. There could be similar factors at play and therefore more research is needed to understand how the dashboards as a new technology fit within the broader management control system of an organization, which has also been suggested by Granlund (2010).

Similarly, one could explore whether the introduction of a dashboard as a complimentary management control tool affects performance appraisal in organizations. A dashboard might for example facilitate more transparency and clarity regarding the way employees are compensated. To some extent, more transparency could drive out biased performance evaluations that are found under traditional performance management systems (Longenecker et al., 1987). Justice literature points out that employees care a great deal about the fairness of the human resources system (e.g.Taylor et al., 1995). Consequently, a more fair and transparent performance evaluation and compensation system through the dashboard could lead to more satisfied and accepting employees, even when the outcomes of the evaluations are less than desirable (Taylor et al., 1998).

Finally, an important question to answer is whether the benefits of dashboards are contingent on some organizational factors such as the management control style. If benefits are contingent on certain factors, then dashboards may not be suitable to all types of organizations. For example, management control in some organizations might be enforced through strong cultural controls instead of result controls. This issue is further discussed under organizational barriers.

Furthermore, should dashboards be used by everyone (e.g. operational staff) in an organization or would the (top) management benefit more? Although, with the right customization (e.g. appropriate KPI's for different individuals and functions) they are likely to benefit many, limitations on financial resources and IT support might hinder their full penetration in the short run. The adoption rate of dashboards is also relevant and important, as it could be subject to the network effect, i.e. consensus on problem diagnosis and consistency of measures could help build a culture of teamwork and shared values.

5.6. Technical Challenges

In this paper, we looked at dashboards from a design perspective. Another aspect to focus on could be the technical challenges and difficulties involved in integrating dashboards with legacy systems and applications that feed data into them. There might be for example a problem with data quality, which was also confirmed through our preliminary interviews with dashboard consultants in Finland. Thus, although users might have access to dashboards, lack of trust in the data might be limiting their use. Also, if performance is an issue, an optimum data refresh rate would need to be established, which would depend on the needs and roles of the users. For example, a call-centre operator might require updates every hour (e.g. unanswered calls per hour), whereas the sales vice president may need only weekly or monthly data. Research is needed that focuses on the above mentioned challenges, suggesting efficient ways to tackle them.

5.7. Other Directions

The performance measures that the dashboards capture and display are just as important as their design features, as the dashboard is only useful insofar as the data it provides is valuable (accurate, complete, relevant and timely). The topic of measurement selection was not part of this paper. However, measurement selection and the dashboard development process are important areas to focus on since a dashboard's success could very well depend on them. Hence, research on dashboard implementation projects (e.g. critical success factors) could be valuable, which was also the subject in Pauwels et al. (2009), albeit conceptually. Also, research could look into more innovative performance measures (e.g. comparative measures) that take advantage of new web technologies (e.g. Web 2.0) and data formats (e.g. Extensible Business Reporting Language). Also, organizations are increasingly using data mining techniques and predictive analytics to discover previously unknown relationships and patterns (e.g. in consumer behaviour), which poses a challenge in terms of presenting the information in the best possible way but also opportunities for new types of performance measures.

Finally, as we mentioned before, dashboards might lead to dysfunctional effects due to increased accountability or distress from being constantly monitored. Research is needed to investigate if this could be the case and what organizations can do to balance the benefits with its potential drawbacks.

6. Conclusions

Technology is pervasive in the accounting profession and the use of information systems has become a must for the achievement of accounting tasks. In the competencies framework of The American Institute of Certified Public Accountants (AICPA), one of the functional competencies for entry into accounting profession is the necessary skill to use technology tools effectively and efficiently. However, it is the responsibility of organizations to adopt decision support tools such as dashboards that fit well with the various tasks of different users, which support rather than complicate the work of employees. Too many IT projects have failed in the past or yielded little benefit. Hence, unlike before, many companies do not have the time and money to experiment with technology and learn by trial and error, which makes the subject of effective dashboard design highly relevant.

Individuals have limited working memory store which may often lead to some of the valuable information to be disregarded during decision making. Dashboards may reduce this effect by optimizing information load and enabling users to focus on the more important and relevant part of the information. Thus, a major challenge is to design dashboards that maximise cognition by capitalizing on human perceptual capabilities. In this paper, we set out to explore how dashboards should be designed (RQ1) and whether the design might need to be contingent on the types of tasks performed and the decision makers' characteristics (RQ2 and RQ3). To our knowledge, this is the first study that specifically addressed dashboard design.

Based on a multidisciplinary literature review, some features emerged as “universal features” that need to be in place in any case, i.e. the visual design features. On the other hand, we found the functional design features of the dashboard to be dependent on the (i) purpose of the dashboard, (ii) tasks, (iii) knowledge, and (iv) personality of the user. Because of this, it is important for the dashboard to incorporate interactivity and flexibility, i.e. to be able to display data in various formats and at different levels of aggregation. This way they can offer an elegant solution to the information presentation format problem, making them useful for both spatial and symbolic tasks, as well as to users with different knowledge (e.g. accounting) and personality (e.g. highly analytic). This is also in line with Huber (1983).

The study makes two contributions. Firstly, the literature review and the identified dashboard features might offer value to practitioners, who are considering implementing dashboards or to those who want to improve on their existing solutions. Secondly, it contributes to the accounting information systems literature by identifying a number of research paths that could give momentum to this under-researched but critical area.

Funding

The authors have received funding from Tekes (The Finnish Funding Agency for Technology and Innovation) for the research and authorship of this article.

References

Amaratunga D, Baldry D. Moving from performance measurement to performance management. Facilities 2002;20(5/6):217–23.
Amer TS. An experimental investigation of multi-cue financial information display and decision making. J Inf Syst 1991;5(2):18–34.
Amer TS. Bias due to visual illusion in the graphical presentation of accounting information. J Inf Syst 2005;19(1):1–18.

Amer TS, Ravindran S. The effect of visual illusions on the graphical display of information. J Inf Syst 2010;24(1):23–42.
Anderson JC, Mueller JM. The effects of experience and data presentation format on an auditing judgement. J Appl Bus Res 2005;21(1):53–63.
Anderson J, Reckers P. An empirical investigation of the effects of presentation format and personality on auditor's judgment in applying analytical procedures. Adv Acc 1992;10:19–43.
Anderson JC, Kaplan SE, Reckers PMJ. The effects of output interference on analytical procedures judgements. Auditing 1992;11(2):1.
Argote L, McEvily B, Reagans R. Managing knowledge in organizations: an integrative framework and review of emerging themes. Manag Sci 2003;49(4):571–82.
Asahi T, Turo D, Schneiderman B. Using treemaps to visualize the analytic hierarchy process. Inf Syst Res 1995;6(4):257–375.
Banker RD, Lee S-Y, Potter G, Srinivasan D. Contextual analysis of performance impacts of outcome-based incentive compensation. Acad Manage J 1996;39:920–48.
Banker RD, Chang H, Pizzini MJ. The balanced scorecard: judgemental effects of performance measures linked to strategy. Account Rev 2004;79(1):1–23.
Bariff ML, Lusk EJ. Cognitive and personality tests for the design of management information systems. Manag Sci 1977;23(8):820–9.
Beattie VA, Jones MJ. Changing graph use in corporate annual reports. Contemp Account Res 2000;17(2):213–26.
Behrens R. Design in the visual arts. Englewood Cliffs, NJ: Prentice-Hall, Inc.; 1984.
Benbasat I, Dexter AS. Value and events approaches to accounting: an experimental evaluation. Account Rev 1979;54(4):735–49.
Bieri J. Cognitive structures in personality. In: Schroder H, Suedfeld P, editors. Personality theory and information processing. New York: The Ronald Press; 1971. p. 178–208.
Blocker E, Moffie R, Zmud R. Report format and task complexity: interactions in risk judgments. Account Org Soc 1986;11(6):457–70.
Boon WT, Tak WL. The impact of interface customization on the effect of cognitive style on information system success. Behav Inf Technol 1991;10(4):297–310.
Bowen PL, Ferguson CB, Lehmann TH, Rohde FH. Cognitive style factors affecting database query performance. Int J Account Inf Syst 2003;4:251–73.
Bricker R, Nehmer R. Information presentation format, degree of information processing and decision quality. Adv Account Inf Sys 1995;3:3–29.
Brunswik E. The conceptual framework of psychology. Chicago: University of Chicago Press; 1952.
Card SK, Mackinlay JD, Schneiderman B. Readings in information visualization: using vision to think. 1st edition. Morgan Kaufmann; 1999.
Cardinaels E. The interplay between cost accounting knowledge and presentation formats in cost-based decision-making. Account Org Soc 2008;33:582–602.
Cardinaels E, van Veen-Dirks PMG. Financial versus non-financial information: the impact of information organization and presentation in a Balanced Scorecard. Account Org Soc 2010;35:565–78.
Carpenter DA, Anders J, Anderson A. Influence of Myers–Briggs type on preference for data presentation format. J Comput Inf Syst 1993;33(4):85–90.
Chenhall R, Morris D. The effect of cognitive style and sponsorship bias on the treatment of opportunity costs in resource allocation decisions. Account Org Soc 1991;16(1):27–46.
Chewning EG, Harrell AM. The effect of information load on decision makers' cue utilization levels and decision quality in a financial distress decision task. Account Org Soc 1990;15(6):527–42.
Choo CW. Information use and early warning effectiveness: perspectives and prospects. J Am Soc Inf Syst Sci Technol 2009;60(5):1071–82.
Corona C. Dynamic performance measurement with intangible assets. Rev Account Stud 2009;14:314–48.
David JS, Dunn CL, McCarthy WE, Poston RS. The research pyramid: a framework for accounting information systems research. J Inf Syst 1999;13(1):7–30.
Davis FD. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q 1989a;13(3):319–40.
Davis LR. Report format and the decision maker's task: an experimental investigation. Account Org Soc 1989b;14(5–6):495–508.
DeBusk GK, Brown RM, Killough LN. Components and relative weights in utilization of dashboard measurement systems like the Balanced Scorecard. Br Account Rev 2003;35:214–31.
Dennis AR, Carte TA. Using geographical information systems for decision making: extending cognitive fit theory to map-based presentations. Inf Syst Res 1998;9(2):194–203.
DeSanctis G, Jarvenpaa SL. Graphical presentation of accounting data for financial forecasting: an experimental investigation. Account Org Soc 1989;14(5–6):509–25.
Diamond L, Lerch FJ. Fading frames: data presentation and framing effects. Decis Sci 1992;23(5):1050–71.
Dilla WN, Steinbart PJ. The effect of alternative supplementary display formats on balanced scorecard judgements. Int J Account Inf Syst 2005;6:159–76.
Doll WJ, Torkzadeh G. Developing a multidimensional measure of system-use in organizational context. Inf Manage 1998;33:171–85.
Eisenhardt KM. Control: organizational and economic approaches. Manag Sci 1985;31:134–49.
Few S. Information dashboard design, the effective visual communication of data. First Edition. O'Reilly Media, Inc.; 2006
Friedman A. Framing pictures: the role of knowledge in automatized encoding and memory of gist. J Exp Psychol Gen 1979;108:316–55.
Frownfelter-Lohrke C. The effects of differing presentations of general purpose financial statements on users' decisions. J Info Syst 1998;12(2):99–107.
Gleser G, Ihilevich D. An objective instrument for measuring defense mechanisms. J Consult Clin Psychol 1969;33:151–60.
Goldstein EB. Sensation and perception. 7th Edition. Thomson Wadsworth; 2007.
Granlund M. Extending AIS research to management accounting and control issues: a research note. Int J Account Inf Syst 2010. xxx:xxx.
Haeckel SH, Nolan RL. Managing by wire: Using IT to transform a business from "make-and-sell" to "sense-and-respond". Harv Bus Rev 1993;5:122–32.
Halford GSR, Baker R, McGredden JE, Bain JD. How many variables can human process? Psychol Sci 2005;16(1):70–6.
Hanoa E. Brain Gain. Accountancy age; 2009. p. 21.
Hard NJ, Vanecek MT. The implications of tasks and format on the use of financial information. J Inf Syst 1991;5(2):33–49.
Hasbun A. (2009) An Empirical Investigation: Do Animated Graphs Improve the Quality of Sales Forecasting Decisions in Comparison to Tables? Master Thesis 2009, Hanken School of Economics.

Heaps C, Handel CH. Similarity and features of natural textures. J Exp Psychol Hum Percept Perform 1999;25:299–320.
Helfman JI, Goldberg JH. Selecting the Best graph based on Data, Tasks, and User Roles, UPA 2007 Conference Patterns: Blueprints for Usability, June 11–15, 2007, Austin, Texas, USA; 2007http://www.upassoc.org/usability_resources/conference/2007/prp_049.pdf. [Last accessed on 25.3.2010].
Hevner AR, March ST, Park S. Design science in information systems research. MIS Q 2004;28(1):75–105.
Heylighen F. In: Heylighen F, Aerts D, editors. The growth of structural and functional complexity during evolution; 1997.
Huang Z, Chen H, Chen G, Fei X, Jennifer J, Wu S, et al. Expertise visualization: an implementation and study based on cognitive fit theory. Decis Support Syst 2006;4:1539–57.
Huber GP. Cognitive style as a basis for MIS and DSS designs: much ado about nothing? Manag Sci 1983;29:567–79.
Hunton James E, Libby D, Libby J, Mauldin E, Wheeler P. Continuous monitoring and the status quo effect. Int J Account Inf Syst 2010;11(3):239–52.
Iselin ER. The effects of information load and information diversity on decision quality in a structured decision task. Account Org Soc 1988;13(2):147–64.
Ittner CD, Larcker DF. Coming up short on nonfinancial performance measurement. Harv Bus Rev 2003;81(11):88–95.
Jarvenpaa S, Dickson GW. Graphics and managerial decision making: research based guidelines. Commun ACM 1988;31(6):764–74.
Jensen M, Meckling W. In: Werin L, Wijkander H, editors. Contract economics. Oxford Blackwell; 1992.
Kaplan RS. An examination of the effect of presentation format on auditors' expected value judgments. Account Horiz 1988;2(3):90–5. [September].
Kaplan RS, Norton DP. The balanced scorecard: measures that drive performance. Harv Bus Rev 1992;70(1):71–9.
Kaplan RS, Norton DP. The balanced scorecard. Boston MA: Harvard Business School Press; 1996.
Kawamoto T, Mathers B. Key success factors for a performance dashboard. DM Rev 2007:20–1.
Kostov V, Fukuda S. Development of Man-Machine Interfaces based on User Preferences. Proceedings of the 2001 IEEE International Conference on Control Applications September 5–7. Mexico City, Mexico; 2001.
Lederer A, Smith GL. Individual differences and decision-making using various levels of aggregation of information. J Manage Inf Syst 1988;5(3):53–69.
Liberatore MJ, Titus GJ, Dixon PW. The effects of display formats on information systems design. J Manage Inf Syst 1989;5(3):85–99.
Longenecker CO, Dennis AG, Sims HP. Behind the mask: the politics of employee appraisal. Acad Manag Exec 1987;1(3):183–93.
MacKay DB, Villarreal A. Performance differences in the use of graphic and tabular displays of multivariate data. Decis Sci 1987;18(4):535–46.
Malina MA, Selto FH. Communicating and controlling strategy: an empirical study of the effectiveness of the balanced scorecard. J Manag Account Res 2001;13:47–90.
Merchant KA, Van der Stede WA. Management control systems. Second Edition. Prentice Hall; 2007.
Mia L, Chenhall RH. The usefulness of management accounting systems, functional differentiation and managerial effectiveness. Account Org Soc 1994;19(1):1—13.
Miller A, Cioffi J. Measuring marketing effectiveness and value: the unisys marketing dashboard. J Advert Res 2004;44:237–43.
Moore P, Fitz C. Gestalt theory and instructional design. J Tech Writ Commun 1993;23(2):137–57.
Mullet K, Sano D. Designing visual interfaces: communication oriented techniques. Englewood Cliffs, NJ: Prentice Hall; 1995.
Nani AJ, Dixon JR, Vollman TE. Strategic control and performance measurement. J Cost Manag 1990:33–42.
Negash S, Gray P. Business intelligence, international handbook on information systems. Handbook on decision support systems. Berlin Heidelberg: Springer; 2008. p. 175—193.
Neumann BR, Roberts ML, Cauvin E. Financial and nonfinancial performance measures. Cost Manage 2008;22(6):5–14.
Newell A, Simon HA. Human problem solving. Englewood Cliffs, NJ: Prentice Hall; 1972.
O'Donnell E, David JS. How information systems influence user decisions: a research framework and literature review. Int J Account Inf Syst 2000;1:178–203.
Oliva A, Mack ML, Shrestha M, Peeper A. Identifying the perceptual dimensions of visual complexity of scenes. Proceedings of the 26th Annual Meeting of the Cognitive Science Society; 2004.
Olivia. Gist of the scene. In: Itti L, Rees G, Tsotsos JK, editors. The encyclopedia of neurobiology of attention. San Diego, CA: Elsevier; 2005. p. 251–6.
Pauwels K, Ambler T, Bruce HC, LaPointe P, Reibstein D, Skiera B, et al. Dashboards as a service: why, what, how, and what research is needed? J Serv Res 2009;12:175–89.
Raschke RL, Steinbart PJ. Mitigating the effects of misleading graphs on decision makers by educating users about the principles of graph design. J Inf Syst 2008;22(2):23–52.
Rasmussen N, Chen CY, Bansal M. Business dashboards, a visual catalogue for design and deployment. Hoboke, New Jersey: John Wiley & Sons Inc.; 2009.
Reich BH, Benbasat I. Measuring the linkage between business and information technology objectives. MIS Q 1996;20(1):55–81.
Rogers EM. Diffusion of innovations. 3rd edition. New York: The free press; 1983.
Roy MC, Lerch FJ. Overcoming ineffective mental representations in base-rate problems. Inf Syst Res 1996;7(2):223–47.
Schulte MF. Business objects dashboard manager. DM Rev 2006;16(2):49.
Schulz A, Booth P. The effects of presentation format on the effectiveness and efficiency of auditors' analytical review judgments. Account Finance 1995;35:107–31.
Seigel-Jacobs, Yates JF. Effects of procedural and outcome accountability on judgment quality. Organ Behav Hum Decis Process 1996;65(1):1–17.
Shields MD. Effects of information supply and demand on judgment accuracy: evidence from corporate managers. Account Rev 1983;58(2):284–303.
Silver MS. Decision support systems: directed and nondirected change. Inf Syst Res 1990;1(1):47–70.
Silver MS. Decisional guidance for computer-based decision support. MIS Q 1991;15(1):105–22.
So S, Smith M. The impact of presentation format and individual differences on the communication of information for management decision making. Manag Audit J 2003;18(1):59–67.
So S, Smith M. Multivariate decision accuracy and the presentation of accounting information. Account Forum 2004;28:283–305.

Sowa J. Notes on ontology. Paper distributed to attendees at The 1997 Bolzano International School in Cognitive Analysis—Categories: Ontological Perspectives in Knowledge Representation, Balzano, Italy, September, 1997; 1997 [to be published in 1999 as Knowledge representation: Logical, philosophical, and computational foundations by PWS publishing Company].

Stocks MH, Harrell A. The impact of an increase in accounting information level on the judgment quality of individuals and groups. Account Org Soc 1995;20(7/8):685–700.

Taylor J. A personality scale of manifest anxiety. J Abnorm Soc Psychol 1953;48:285–90.

Taylor MS, Tracy KB, Renard MK, Harrison JK, Carroll SJ. Due process in performance appraisal: a quasi-experiment in procedural justice. Adm Sci Q 1995:40.

Taylor MS, Masterson SS, Renard MK, Tracy KB. Managers' reactions to procedurally just performance management systems. Acad Manage J 1998;41(5):568–79.

Tetlock PE, Boettger R. Accountability amplifies the status quo effect when change creates victims. J Behav Decis Mak 1994;7:1–23.

Tornatzky LG, Fleischer M. The processes of technological innovation. Lexington, Massachusetts: Lexington Books; 1990.

Tufte ER. The visual display of quantitative information. Cheshire, CT: Graphics Press; 1983.

Tufte ER. Visual display of quantitative information. Graphics Press; 2006.

Tuttle B, Kershaw R. Information presentation and judgment strategy from a cognitive fit perspective. J Inf Syst 1998;12(1):1–18.

Umanath NS, Vessey I. Multiattribute data presentation and human judgment: a cognitive fit perspective. Decis Sci 1994;25(5/6): 795–824.

Vaassen E, Baker C, Hayes R. Cognitive styles of experienced auditors in Netherlands. Br Account Rev 1993;1993:367–82.

Vessey I. Cognitive fit: a theory-based analysis of the graphs versus tables literature. Decis Sci 1991;22(2):219–40.

Vessey I, Galletta D. Cognitive fit: an empirical study of information acquisition. Inf Syst Res 1991;2(1):63–84.

Wainer H. Visual revelations: graphic tales of fate and deception from Napoleon Bonaparte to Ross Perot. New York, NY: Copernicus/Springer-Verlag; 1997.

Webster J, Watson RT. Analyzing the past to prepare for the future: writing a literature review. MIS Q 2002;26(2):xiii–xxiii.

Wheeler P. The Myers–Briggs type indicator and applications to accounting education and research. Issues in Accounting Education; 2001.

Wieresma E. For which purposes do managers use Balanced Scorecards? An empirical study. Manage Account Res 2009;20:239–51.

Wilson EV, Zigurs I. Decisional guidance and end-user display choices. Account Manage Inf Technol 1999;9:49–75.

Wind Y. Marketing as an engine of business growth: a cross-functional perspective. J Bus Res 2005;58(7):863–73.

Witkin H, Dyk R, Paterson H, Goodenough H, Birnbaum J. Psychological differentiation. . 1961New York: John Wiley; 1962.

Wright WF. Superior loan collectability judgments given graphical displays. Auditing: J Pract Theory 1995;14(2):144–54.

Wunsche B. A survey, classification and analysis of perceptual concepts and their application for the effective visualization of complex information. Proceedings of the 2004 Australasian symposium on Information Visualisation. Darlinghurst, Australia: Australian Computer Society, Inc.; 2004. p. 17–24.

Ziff Davis Enterprise. Reaping the benefits of next generation dashboards. available at White Pap 2008:1–4 http://portals.tdwi.org/whitepapers/2009/02/the-next-generation-of-enterprise-reporting-business-intelligence-reporting-tools-birt.aspx. [Last Accessed on 7.5.2009].