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Business intelligence & analytics in management accounting research: Status and future focus

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ABSTRACT

Executives see technology, data and analytics as a transforming force in business. Many organizations are therefore implementing business intelligence & analytics (BI&A) technologies to support reporting and decision-making. Traditionally, management accounting is the primary support for decision-making and control in an organization. As such, it has clear links to and can benefit from applying BI&A technologies. This indicates an interesting research area for accounting and AIS researchers. However, a review of the literature in top accounting and information systems journals indicates that to date, little research has focused on this link. This article reviews the literature, points to several research gaps and proposes a framework for studying the relationship between BI&A and management accounting.

1. Introduction

Business intelligence and analytics (BI&A) technologies facilitate data collection, analysis and information delivery and are designed to support decision-making. Given that management accounting (MA) is a decision-supporting activity, there is an obvious link between BI&A and management accounting (AICPA, 2013; Cokins, 2009; Maisel and Cokins, 2014). This link is important, as BI&A is high on the corporate agenda of many organizations (Colombus, 2014; Colombus, 2015; Research and Markets, 2015; PwC, 2016), and executives believe that better data analysis and decision support create value for their companies (Elbashir et al., 2013; Kiron et al., 2014). Thus, management accounting has much to gain from successfully integrating BI&A techniques into managerial accounting tasks. This interest is also reflected in the professional accounting bodies' agendas, so much so that in 2016, the Chartered Institute of Management Accountants (CIMA) called for research on 'analytics' by offering grants to undertake studies in this area (CIMA, 2016b).

Given the current business focus on BI&A and its perceived management importance, this solution domain should be an area of focus of AIS research. However, commentators have noted that although "there is potential for studying business intelligence solutions in general and their implications for decision making and control, our current understanding of these developments in the accounting academia is very limited" (Granlund, 2011, p. 10).

To assess whether these reservations are valid, an extensive literature search is carried out in over sixty accounting and information system journals. Literature reviews are essential, as they save time and effort for future researchers and lead to the efficient advancement of new knowledge and of the discipline (Webster and Watson, 2002). The specific aims of this review are twofold:

1. Critically review and evaluate the volume and content of literature that has focused on the relationship between BI&A and

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management accounting.
2. Based on the review, highlight research gaps and opportunities for future research.

This paper is structured as follows. Section 2 conceptualizes the link between MA and BI&A. This is necessary, as there are numerous definitions of BI&A in use and there is some confusion regarding how this technology is linked to other emerging technologies such as big data, machine learning and the Internet-of-things. Section 3 explains the two-staged literature review, initially providing a review of the recent themes in the IS literature and then giving an overview of the articles selected for the second review on the link between management accounting and BI&A. Section 4 contains the review and the findings, organized into 5 themes identified during the analysis of the articles and a summary of research questions to be explored in the future. Section 5 concludes the paper.

2. Conceptualizing management accounting and BI&A

Several previous literature reviews in the AIS field were examined to determine any focus on BI&A. Sutton gives an overview of AIS research and its focus areas based on articles published in the International Journal of Accounting Information Systems (Sutton, 2000, 2010). This review lists four areas of AIS research: enterprise systems, the value of IT, computer auditing and knowledge systems. BI&A is not listed as a separate area in this review. Poston and Grabski (2000) and Ferguson and Seow (2011) provide an overview of the AIS research published in various journals. These reviews do not address BI&A specifically but include "Judgment and decision-making", "Databases", and "Expert systems, artificial intelligence and decision-aids" as separate topics that contain BI&A-related themes. There is no specific reference to management accounting, and there is no theoretical framework developed to classify the research reviewed into a coherent framework like those developed by Mauldin and Ruchala (1999) or Hartmann and Vaassen (2003). A literature review by Rom and Rohde (2007) does this by specifically focusing on management accounting and integrated information systems, although BI&A technology is not a part of that review.

In conceptualizing management accounting, 4 main elements are defined for guiding the literature review and discussing its links to BI&A (Rom and Rohde, 2007). First, there are the overall tasks of the management accounting function or what Granlund and Lukka (1998) have called the "doing" of management accounting in the everyday life of the organizational actor (Granlund and Lukka, 1998). Although these can vary, the main ones comprise planning, control, performance measurement, transaction processing, reporting and decision support (Atkinson et al., 2011; Rom and Rohde, 2007; Booth et al., 2000). Second, there are the specific management accounting techniques that are used in carrying out management accounting tasks, such as activity-based costing, balanced scorecard frameworks, volume-based allocation of costs, strategy maps, zero-based budgeting, and forecasting (Granlund and Malmi, 2002; Seal et al., 2014; Armitage et al., 2016). While MA refers to tasks and techniques, management control is much broader and includes other controls such as personal and clan controls in addition to MA practices to achieve a certain goal (Chenhall, 2003). The third is the organization of management accounting, which includes the roles of the management accountants in organizations and how management accounting functions are organized across industries, cultures and organizational types (Quattrone and Hopper, 2005; Williams and Seaman, 2001). Finally, there is the impact management accounting has on organizational behaviour and management's perception of management accounting issues (Dechow and Mouritsen, 2005; Janke et al., 2014; Long, 2012).

Research has long investigated the impact of various information technologies on all four elements. For example, a stream of research has focussed on how the adoption of ERP systems (or integrated information systems) affect management accounting tasks and techniques. Although these systems have no doubt increased the efficiency of collecting and reporting accounting data (Cooper and Kaplan, 1997; Davenport, 1998), many have concluded that they often have stabilising effects on management accounting practices rather than engendering any direct or signinficant changes (Granlund and Malmi, 2002; Rom and Rohde, 2007; Scapens and Jazayeri, 2003). Neverheless, ERP systems enable better control (Chapman and Kihn, 2009; Granlund and Malmi, 2002; Rom and Rohde, 2007; Scapens and Jazayeri, 2003; Wagner et al., 2011) and affect organizational performance positively (e.g., Hunton et al., 2003; Nicolaou, 2004; Nicolaou and Bhattacharya, 2006; Velcu, 2007). Also, studies have looked at the changing role of the management accountant because of the digitization of accounting processes. While management accountants' roles have become more business-oriented and strategic, almost consultant-like (Granlund and Malmi, 2002; Quattrone and Hopper (2001)), better access to information has led to the decentralization of the management accounting function, where management accounting tasks are increasingly performed in other functions of an organization (Caglio, 2003; Rom and Rohde, 2007).

BI&A is defined here as a technology and a process for analysing data and presenting actionable information to help organizational decision makers make better decisions (Chaudhuri et al., 2011; Howson, 2007; Davenport, 2006, 2010, 2013, 2014; Sharda et al., 2014). BI&A is an "umbrella term" in that it encompasses a variety of technologies and methodologies that enable organizations to collect data from internal and external sources, prepare it for analysis, develop and run queries against the data, and create reports, dashboards and data visualizations to make the results available to end users. In this paper, we adopt the definition of Chen et al. (2012) for BI&A, which among others, includes emerging areas in analytics such as the analytics for mobile and sensor-based content and, more generally, big data (Chen et al., 2012).

Based on the technical literature of several leading BI&A vendors (Gartner, 2017), there are four basic technological elements of BI&A applications in any organization (Chae and Olson, 2013; Chaudhuri et al., 2011; Elliot and Woodward, 2015; Howson, 2007, 2013; Howson and Arnold, 2013; Sheikh, 2013; Troyansky et al., 2015; Volitich and Ruppert, 2012). These are (i) Infrastructure (e.g., cloud-based infrastructure relational or non-SQL databases); (ii) Data management (e.g., integration of internal and external data); (iii) Data analyses (e.g., statistical techniques and artificial intelligence); and (iv) Information Delivery (e.g., dashboards). These elements are integrated, meaning that without infrastructure, data cannot be effectively and efficiently captured and stored; without

Table 1
Literature review.

	Review 1	Review 2
Keywords	Business intelligence, analytics, big data, decision support	Business intelligence, analytics, big data, decision support, visualization … AND accounting, costing, budgeting, performance measurement, etc.
Journals	A* ranked ABDC journals Code 0806 (IS/IT)	A* and A ranked ABDC journals Code 1501 (accounting), Code 0806
Years	2010–2015	2005–2015
Number of papers	32 papers from 9 journals (out of 13)	30 papers from 17 journals (out of 67)

*Australian Business Deans Council Quality List 2013.

data management technologies, analysis technology cannot be deployed; and without information delivery to decision makers, analysis does not have any value. These building blocks are often referred to as the "technology stack" or "architecture stack" of BI&A (Evelson, 2008, 2017). This focus includes earlier conceptualizations of this type of technology, such as Decision Support Systems (DSS), Executive Information Systems (EIS) and Management Information Systems (MIS). It should be noted that modern BI&A solutions are technologically more advanced than earlier DSS, EIS and MIS solutions. Particularly in terms of usability, data management, including data type, the sophistication of techniques for analysis and visualization/reporting capabilities (Chen et al., 2012). However, the fundamental purpose of these solutions remains the same: To gather, process and analyse data in order to improve decision making by managers.

3. Literature review: method and organizing framework

A two-tiered strategy was adopted for the literature search and review. First, a general review of the academic information system (IS) literature on BI&A-related topics was carried out. This was done to establish the foundations of BI&A in terms of its use and value more generally and what cutting-edge knowledge exists in the technology domain. The first review guided the second stage review of the literature in the accounting domain regarding what themes to focus on and what gaps might exist. While the details of the two stages are explained further below, Table 1 provides a brief overview of the literature review.

3.1. Method

In selecting the journals for the first review, the Australian Business Deans Council (ABDC) journal quality list from 2013 for IS/IT (Information Systems/Information Technology) (Code 0806 in the ABDC) was used (ABDC, 2013). The ABDC list is consistent with other widely accepted journal quality lists such as the Academic Journal Guide and SCIMAGO for top-ranking journals. The keywords used for selecting the papers were "business intelligence", "analytics", "big data", and "decision support". Only A* ranked journals (13 in total) were included in the review to focus the review on higher-quality outlets. The search was limited to 2010–2015 to limit the search to the most recent research and to acknowledge the rapid technological development in the field. The search returned 32 papers from 9 journals (see Appendix 1).

The papers in the journals addressed various issues with respect to the design, adoption and use of BI&A. The topics addressed in these papers could broadly be categorized into three themes: (i) BI&A infrastructure and data management (6 papers); (ii) BI&A acceptance and success (12 papers); and (iii) big data and future BI&A trends (14 papers). Nine of the 10 'big data' papers were conceptual or commentaries, 7 papers used surveys to collect data, and 6 adopted an experimental design. We draw on these studies and themes when we later discuss existing research of BI&A in management accounting and when identifying research gaps.

The second stage of the review included a search for literature that focused on BI&A and management accounting in both IT/IS and accounting journals. The search focused on journals within accounting (Code 1501 in the ABDC) and - as in the first literature search - IS/IT (Information Systems/Information Technology) (Code 0806) from the ABDC journal quality list. This search included journals ranked A* and A. This was consistent with other review studies in management accounting and IT that only looked at higher-quality journals (Luft and Shields, 2003; Piccoli and Ives, 2005).

It was decided to search for literature in two periods. The first period, as described above, was 2010–2015. This was done to reflect a certain level of technological development, as before 2010, the technological development of BI&A was limited compared to today. For example, interactive dashboards were less known, analytical methods were constrained by processing capacity, big data was not in focus, and infrastructure choices for BI&A were less advanced. However, it was decided to also search for literature in the period 2005 to 2009. This was to capture any earlier BI&A and MA research topics that might have relevance regardless of technological developments.

Finally, IS/IT journals that focus on specific types of technology, such as the International Journal of Medical Informatics and Information Society were excluded given the little relevance to accounting. This resulted in 67 journals, which are listed in Appendix 3.

To cast the net as widely as possible, the search terms used in the second review were combinations of "accounting", "costing", "performance measurement/management", "budgeting" with "business intelligence", "analytics", "data management", "visualization", "decision aids", "decision support", "information delivery", "big data" and "information systems". The research methodology of all empirical studies was also noted. Studies that had no relevance to management accounting were discarded after separate

Table 2
Number of papers addressing BI&A and management accounting.

Accounting journals (rating)	2005–2009	2010–2015
Accounting, Organizations and Society (A*)	0	1
Journal of Accounting Research (A*)	0	1
The Accounting Review (A*)	0	1
Accounting and Business Research (A)	0	2
Accounting Horizons (A)	0	3
Accounting and Finance (A)	0	1
Behavioral Research in Accounting (A)	0	2
International Journal of Accounting Information Systems (A)	3	2
Total Papers in Accounting Journals = 16	3	13
IS journals (rating)		
Decision Support Systems (A*)	0	1
European Journal of Information Systems (A*)	0	1
Information and Management (A*)	1	0
Information Systems Research (A*)	0	1
Journal of Management Information Systems (A*)	0	1
Journal of Strategic Information Systems	1	0
Business & Information Systems Engineering (A)	0	1
International Journal of Information Management (A)	0	3
Journal of Information Systems (A)	1	3
Total Papers in IS/IT Journals = 14	3	11

reviews by the researchers. For example, a study by Işık et al. (2013) on BI&A did not qualify, as it had no relevance to management accounting or even accounting, although this paper was included in the first review. Finally, to avoid omitting significant papers that did not meet the selection criteria, we did a search in Google Scholar for highly cited papers (100 or more citations in total) for years 2005–2015. This was similar to a procedure followed by West and Bogers (2014). We found only one additional paper (Lee and Park, 2005), which we included in our review in Section 4.

3.2. Overview of studies of BI&A and management accounting

In all, only 30 articles were found that combined a research focus on BI&A and management accounting in 16 separate journals. Given the voluminous research into management accounting topics in general and research of, for example, enterprise systems and continuous monitoring in particular, this is a relatively low number. Three of these articles were also included in the first review, as they appeared in A* IS journals. An overview of each paper is given in Appendix 2. This includes the research topic, methodological approach and the use of theory.

The distribution of publication dates - falling into the two periods selected - is shown in Table 2.

Table 3 presents the type of research methods that were applied in the papers reviewed. Most of the papers were conceptual or applied an experimental methodology.

Generally, there were many conceptual papers compared to empirical studies, as only 19 papers in the last 10 years have provided empirical evidence on applications of BI&A in management accounting. This might be an indication of the emergent nature of the research on BI&A in accounting in general and in management accounting in particular, but it signals a lack of empirically based knowledge in the field. Table 2 shows a certain increase in BI&A and management accounting research after 2010, perhaps indicating a rising interest in the subject. The most popular methods were experiments focusing on BI&A-related data presentation, while the other themes were explored using a variety of methods apart from big data, where all the papers were conceptual.

It was notable that many of the North American A* journals in accounting, such as the Review of Accounting Studies and the Journal of Accounting and Economics, did not publish any papers on BI&A despite an increasing trend of AIS papers in A* journals in general (Ferguson and Seow, 2011). The International Journal of Accounting Information Systems had the highest number of published papers (5) on the topic, followed by Accounting Horizons, due to the special issue on ‘big data’, and the Journal of

Table 3
Research methods used.

Research methods	Number of papers 2005–2015	% of total
Conceptual (including theoretical, model building and commentaries)	10	33%
Experimental	8	27%
Surveys	6	20%
Case studies and interview-based studies	4	14%
Literature reviews	1	3%
Archival	1	3%
Total	30	100%

Table 4
Research themes addressed in the literature.

Research themes	Number of papers 2005–2015	% of total
1. Information delivery and system feedback for management accounting tasks	10	33%
2. BI&A to improve management accounting tasks and techniques	10	33%
3. Big data's impact on management accounting	4	13%
4. Use and satisfaction with BI&A in management accounting contexts	4	13%
5. BI&A and data quality	2	7%
	30	100%

Information Systems, with three papers each. The IS/IT journals, although having a high number of papers focusing on BI&A-related issues, contain relatively few papers specifically focusing on accounting.

The reason for this lack of focus of highly ranked accounting journals on BI&A and highly ranked IS/IT journal on accounting could be, first, the relatively low number of researchers focusing on AIS in general and BI&A in particular, and second, a lack of exposure of academics to the relatively complex technical issues of BI&A impacting understanding and interest in pursuing research in this area. A third reason might be the traditional functional organization of academic institutions deterring cross-functional research initiatives, where accounting and IS/IT expertise are combined.

Twenty-four of the papers did not use a specific theory (see Appendix 2), as many were either commentaries such as papers on big data or they drew on established principles in decision making (e.g., satisficing), IT (e.g., user satisfaction, ambidexterity), or organizational theory (e.g., absorptive capacity, assimilation). The remaining studies used theories in cognitive psychology, such as cognitive fit theory (Dilla et al., 2013), cognitive load theory (Chen and Koufaris, 2015), dual-coding theory (Tang et al., 2013), or the theory of technology dominance (Mascha and Smedley, 2007).

3.3. Organizing framework

After reading through the papers and determining what research topics were being addressed, the papers were grouped into five themes. The researchers did this first individually. Then, the resulting themes were analysed and discussed until a consensus was achieved. A small number of the papers fell under more than one theme. In such cases, each paper was classified according to the dominant theme addressed. Table 4 gives an overview of the research themes addressed in the papers reviewed.

BI&A and MA were conceptualized in Section 2 (Conceptualizing management accounting and BI&A). Based on the elements of BI &A and MA, we propose the organizing framework below (Fig. 1). The five themes identified from the literature review combine various elements of both BI&A and MA. The themes are presented and discussed in the next section, along with the research gaps for each theme.

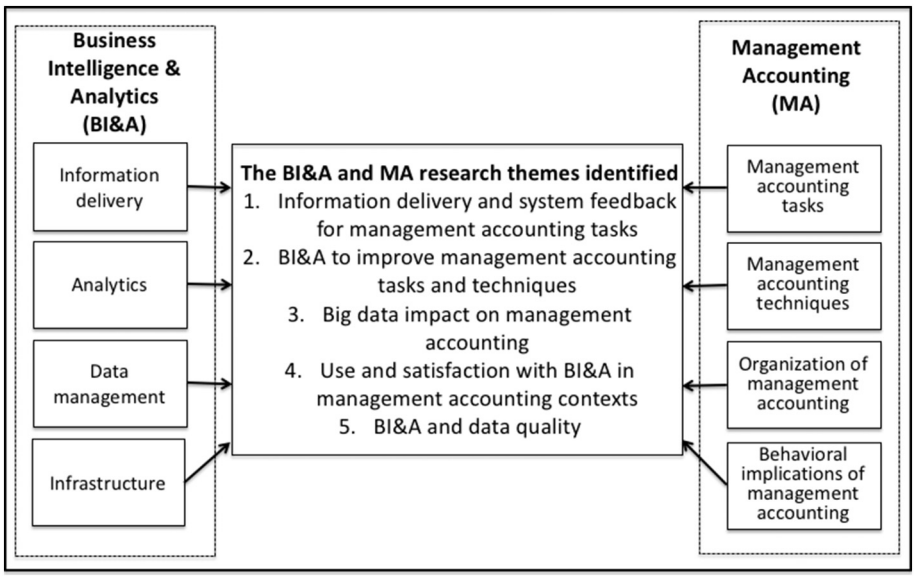

Fig. 1. Five focus areas for research in Business Intelligence & Analytics and Management accounting.

4. BI&A in management accounting research: themes and research gaps

4.1. Information delivery and system feedback for management accounting tasks

4.1.1. Current research focus

With a total of 10 studies, this theme had a relatively high number of papers. Eight of the papers were based on experiments, whereas the remaining two were literature reviews. Overall, the aim of the studies and the theme was to determine the optimum way to present data in terms of visualization, interactivity and system feedback to support decision-making.

Much of the research draws on earlier works regarding the utility of graphical displays over tabular data and cognitive fit theory (Vessey, 1991; Vessey and Galletta, 1991; Umanath and Vessey, 1994). The reviewed studies focused on one or several of the three following features: (i) how the information is presented, namely, in tabular or graphical format; (ii) the level of interaction in terms of the ability to select, navigate, and drill down information; and (iii) the type of feedback provided by the system. Consistent with cognitive fit theory, many of the reviewed studies conclude that decision quality improves when there is a fit among the presentation format, the tasks, and the knowledge of the user (Yigitbasioglu and Velcu, 2012; and Dilla et al., 2010). Furthermore, while the visualization and interactivity of accounting data may enhance decision-making, these features may introduce bias if not designed carefully.

Traditionally, the quest for fit among the presentation format, the task, and the end-user was at the mercy of the designer (either system designers or management accountants) of the reporting system. In contrast, modern BI&A solutions incorporate greater levels of flexibility that allow end-users to dynamically control the presentation of data and therefore the fit between the format and the task without having to rely on a designer to do this. This poses a challenge, as managers might resort to satisficing behaviour when they fail to fully utilize multidimensional hierarchical data due to effort minimisation. Specifically, in the absence of fit between the presentation format and the type of task, drill-down paths can lead to suboptimal decisions (Peng et al., 2007). Similarly, while graphical display and interactivity (selection and links) simultaneously improve confidence and calibration (the difference between the belief that the best decision was made and the quality of the decision outcome), in the absence of one of the two features, a deterioration in both measures can occur (Tang et al., 2013). However, not all studies report value in presentation format interactivity. For example, Locke et al. (2015) find that interactive data made no difference for locating and integrating data to improve investment decisions. Thus, the value of BI&A features seems to be determined by the decision context and tasks at hand. Also, the degree of choice is a factor that increases the overconfidence of the user, as having more options increases the sense of control (Chen and Koufaris, 2015).

Research also indicates that users adopt different decision-making strategies depending on their knowledge and cognitive abilities (Yigitbasioglu and Velcu, 2012; Dilla et al., 2010). Consistent with the holistic decision-making strategy, individuals with low-level task-specific knowledge rely on graphical displays to reduce cognitive effort (Benbasat and Schroeder, 1977). On the other hand, users with high-level task-specific knowledge apply an analytical strategy and rely more on textual information to process specific data items. Thus, acknowledging users' level of knowledge is essential when designing decision support systems, because they may aggravate bias in novices' decision-making (Arnold et al., 2004). Consistent with these theories, Dilla et al. (2013) find that the graphical display of pro-forma earnings information affects the judgment and decision making of individuals differently depending on their task-specific knowledge and experience. For simple tasks (e.g., evaluating the current year's performance), individuals with relatively high levels of task experience do not rely on graphical displays. On the other hand, for complex tasks (e.g., investment judgment), individuals with high levels of task experience rely less on graphical display than individuals with low levels of task experience.

Another area of research is system feedback or recommendations. Advanced BI&A systems can draw attention towards patterns or correlations (e.g., correlate internal costs data with external data) that may be relevant for the task (e.g., budgeting) at hand, as well as warn the user of potential cognitive biases in decision-making such as fixation on financial measures (Cardinaels and van Veen-Dirks, 2010). On the other hand, excessive dialogues may limit the decision space of the user for less-structured tasks that require multiple information sources, such as budgeting. Thus, designers of BI&A are advised to incorporate system feedbacks with caution, as they may constrain and bias user behaviour. For example, Seow (2011) suggests that restricted interaction with the decision support system in terms of system prompts may introduce bias to decisions, as users may fail to adequately address issues not identified by the system. It is also recommended that system feedback be tailored according to the type of task and user knowledge. Mascha and Smedley (2007) report that more feedback is more helpful with less-complex tasks, and the reverse is true for more-complex tasks, as it may lead to deskilling of accountants. Also, system recommendations that contradict the user can lead to the discounting of recommendations and seeing the system as a threat (Jensen et al., 2010; Elkins et al., 2013). However, end-users would benefit from recommendations in the form of theory-guided advice at runtime to help them choose an appropriate presentation format that fits with the task and expertise (Wilson and Zigurs, 1999). End-users may also require additional task-relevant guidance while performing certain activities through system prompts. For example, the system can alert the user when satisficing behaviour is observed so that important granular data are further explored.

Expertise also plays a role in the way users interact with a BI&A. Jensen et al. (2010) study the differences between novice and professional users in the use of an expert system (Jensen et al., 2010). As expected, novice users relied more on the recommendations of the system, and both novices and professionals improved decision- making accuracy when using the system. Contrary to the theory of technology dominance, novices and professionals did not interact with the system differently, and both groups often discounted recommendations. Given rapid advancements through, e.g., artificial intelligence, these systems will increasingly challenge expert users. Better training, interface design and affirmation may improve objectivity in regard to expert systems, reduce threat and even

improve acceptance (Elkins et al., 2013).

Even if BI&A are designed to improve decision-making, some BI&A features may introduce bias and lead to suboptimal decision outcomes. Chen and Koufaris (2015) find that the degree of choice presented by the system and familiarity with the system through user training may encourage risky behaviour (Chen and Koufaris, 2015). Furthermore, the degree of choice increases overconfidence in one's decision, which is when the chances of success at a task are overestimated compared to what would be warranted by objective analysis (Kottemann et al., 1994). Thus, designers of BI&A need to be vigilant when configuring the features of a system and how data are presented in order to reduce the burden on the user. Other features may speed up or improve decision-making. For example, dimensionally modelled data usability is equally beneficial or superior to operationally modelled data in most cases in terms of accuracy, speed and subjective evaluation of data (Vujošević et al., 2012). Dimensional modelling has advantages in giving a holistic view of business and subjective perception, which makes it worthwhile to invest in such features.

These findings have implications for the design of performance dashboards, which is an emerging topic whose design draws on scorecards and visualization of multidimensional financial and non-financial data. As managers tend to discount non-financial measures when evaluating data in scorecards, Cardinaels and van Veen-Dirks (2010) recommend the use of performance markers to reduce bias towards financial performance measures. On the other hand, Chen et al. argue that a manager's awareness of strategically linked performance measures is more important than the format of the balanced scorecard for better decision making (Chen et al., 2016). In conclusion, performance dashboards are effective when their purposes are aligned with their functional and visual design features and are flexible (or customisable) and tailored for the specific type of user (Yigitbasioglu and Velcu, 2012).

4.1.2. Research gaps

While research to date has focussed on the use of tables versus graphs of numerical data exclusively, the use and effectiveness of other visualization techniques in MA tasks for complex data (big data) are yet to be explored. Specifically, are there visualization techniques for qualitative data that can be useful for planning and control? What visualization techniques or dashboards work well with big time series data or probabilistic forecasting? Also, what visualization techniques are appropriate for more-complex techniques, such as clustering and correlation analysis? There is a lack of knowledge and empirical evidence regarding the extent of use of visualization techniques in management accounting and their relative effectiveness. Thus, case studies illustrating the use and effectiveness of advanced BI&A visualization techniques in management accounting would be particularly welcome.

Furthermore, given the importance of 'fit' in visualization, it would be valuable to map the required features of a system to the various tasks in management accounting. To elaborate, certain tasks such as budgeting may require more interactivity or system recommendation, whereas monitoring performance may not. Thus, further research could highlight the features that are most appropriate for certain tasks while considering the potential for bias when suggesting a particular feature or lack thereof.

Additionally, visualization with intelligence feedback opens up the path for linking artificial intelligence to the display of information both in selecting an appropriate visualization that fits the user (e.g., functionality of solutions such as Tablaeu and Qlik (Troyansky et al., 2015)) and the task as well as help with the visual analysis and interpretation of the data. All of these issues need to be explored further. Regarding the new ways of visualizing performance through dashboards, scorecards, live feeds, and social media apps/approaches (e.g., "likes"), how do such solutions affect the perceptions and motivation of employees? Granlund (2011) points out that the functional configuration of IT solutions determines the impacts and effects and that IT is not a "black box". That is to say, dashboards can be set up in a variety of ways that are not all equally good in a given context. This will also apply to data management tools and analytical methods. Therefore, there is a need for the researcher to "interact with technology" to be able to meaningfully study certain topics.

In this new reality where end-users have direct access to data and can apply sophisticated user-friendly analytical and visualization tools to generate decision-relevant information, management accountants might need to carve out new roles as their "monopoly" over reporting cedes. It is likely, for example, that management accountants will no longer be designers of management reporting systems. Rather, it would be expected that they would (i) adopt a consultative role towards end-users, assisting them in selecting and interpreting decision-relevant data and would (ii) play a more active role in assisting IT personnel in choosing the features of BI&A solutions for end-users to find the best match between the features of the BI&A system and those of the requirements and characteristics of the users within an organization.

Furthermore, as information technology changes tasks such as data registration and reporting, the value of creating knowledge from data increases. Another emergent role for management accountants would be to combine their expertise in areas such as cost structures, profitability analysis, revenue streams and management control with the application of new analytical methods. To do this, they need to be trained in data analysis methods, interpretation of data and data presentation, and they must cooperate with emerging analytical functions in organizations (Phillips, 2013).

4.2. BI&A to improve MA tasks and techniques

4.2.1. Current research focus

Ten papers (11 including one highly cited paper) focused on the impact of BI&A on how management accounting tasks (planning, control, performance measurement, etc.) and techniques (activity-based costing, balanced scorecard, zero-based budgeting, etc.) were performed. Three of the studies were conceptual, while the others were either quantitative or qualitative. The overarching question that the studies in this theme addressed is what management accounting tasks and decision contexts BI&A application affects and how their use impacts different measures of performance.

More specifically, a number of studies focused on the link among BI&A, management accounting tasks and organizational

performance to illustrate the value of BI&A (Bronzo et al., 2013; Elbashir et al., 2008; Elbashir et al., 2013; Vukšić et al., 2013). Several papers also looked at how BI&A supports specific accounting tasks, such as profitability analysis (Kowalczyk and Buxmann, 2015; Bronzo et al., 2013); reporting, consolidation and planning (Marx et al., 2012); and sustainability accounting (Petrini and Pozzebon, 2009).

BI&A solutions are used in performance management as a tool to provide performance information to knowledge workers so that they make the right decisions and take the right actions (Vukšić et al., 2013). While BI&A affects business process performance, management control (Elbashir et al., 2011) and organizational performance (Elbashir et al., 2008), it is important that BI&A be assimilated through shared knowledge and strategic support from top management (Elbashir et al., 2013). However, performance measurement processes and the use of BI&A tools in the context of business process management can be misaligned in practice, so it is important to match needs, capabilities and BI&A tools (Vukšić et al., 2013).

BI&A supports several management accounting tasks, such as cost forecasting, product profitability analysis, the financial impact of production changes, and assessments of customer segment profitability (Bronzo et al., 2013; Lee and Park, 2005). The use of BI&A-supported analytical methods improves organizational performance in several dimensions, including financial, customer, process and learning & growth (Bronzo et al., 2013). Many BI&A software solutions are also available for planning, reporting and consolidation tasks (Marx et al., 2012). Both technical characteristics and application characteristics determine the level of maturity for BI&A application in planning, reporting and consolidating in companies. The five-stage maturity model developed by Marx et al. (2012) can be used to map a company's BI&A maturity regarding these tasks and plan further developments. BI&A can be used in different types of routine and non-routine decisions, including product pricing decisions and the choice of product mix (Kowalczyk and Buxmann, 2015). However, there are tensions in implementing data-centric decision-making in organizations. These include tensions between the flexibility and stability of methods and data sources, tensions involving the complexity and understandability of analysis methods, and tensions between broad and focused scopes of analyses. A number of tactics can be used to achieve ambidexterity and resolve these issues.

4.2.2. Research gaps

BI&A provides data-centric decision support to management accountants in, for example, planning, performance measurement and cost management techniques. Many BI&A tools on the market come with standardized models and user-interfaces for Balanced Scorecards, Strategy Maps, and Activity-Based Costing analysis (Troyansky et al., 2015; Volitich and Ruppert, 2012). While analytics-driven management accounting techniques seem to improve the performance of some tasks, they increase decision makers' cognitive load and bias. To overcome the limitations of BI&A and bias, organizations and particularly management accountants require a better understanding of (i) the decision-making process itself, (ii) the nature of the task, and (iii) user requirements. There is also a need to foster an analytics decision-making culture, as it moderates the use of BI&A in an organization (Popovič et al., 2012). Thus, there are many unknowns with respect to the role of management accountants in organizational strategies supported by analytics.

Implementing BI&A analysis techniques to support management accounting techniques can lead to tensions that affect the implementation success (Kowalczyk and Buxmann, 2015). For example, should management accounting expand the scope of data to include external data as well or should it continue to rely mainly on internal data? Should it apply complex statistical analysis methods that might not be understood by business users, or should it continue to rely on simple, proven management accounting techniques? Should it encroach on the domain of other functions by, e.g., using marketing and human resource data in its decision support, or should it stick to the accounting domain? Management accountants would benefit from empirical evidence and theoretical guidance regarding these issues.

The impact of analytics on the relevance and applications of management accounting tasks and techniques has not been explored (Schneider et al., 2015). For example, how do analytical techniques using external data affect revenue and cost forecasting? What does this mean for budgeting and new budgeting practices such as Beyond Budgeting, where forecasting plays a prominent role (Østergren and Stensaker, 2011)? What are the impacts on the budgeting process and forecasting quality in terms of timeliness and accuracy? Will better analytical (costing) models of the organization potentially increase the use of, for example, zero-based budgeting or scenario and contingency planning?

Research is also needed to see whether SMEs take advantage of cloud-based BI&A solutions, which are increasingly being “servitized” (Delen and Demirkan, 2013). Cloud-based solutions may be instrumental in helping to close the know-how gap between small and large organizations in terms of the use of advanced management accounting techniques (Ates et al., 2013).

4.3. Big data's impact on management accounting

4.3.1. Current research focus

The four articles that addressed big data and accounting were all conceptual. None of them referred to any academic empirical work apart from anecdotal evidence. Overall, they focus on what big data is in the context of accounting and what are the likely implications for management accounting, financial accounting and auditing.

The general consensus is that big data will be a disruptive force in accounting in general. The data registration task of accounting will become less important, make some management accounting techniques obsolete, change the role of accounting in decision making processes and require significant changes in the skill sets of management accountants.

Specifically, big data implies real-time registration of internally and externally generated data. This includes regular transaction data as well as data from, e.g., sensors on machines, RFID chips in components, clickstreams from corporate webpages and “data-exhausts”, which include data that are usually not collected, such as the digital trail of customer browsing websites (Bhimani and

Willcocks, 2014). It also includes external data, such as demographic data, weather data and social media feeds. Traditional financial bookkeeping will develop towards a specialized function aimed at providing internal and external stakeholders with a unified "scoreboard". However, the role of bookkeeping in creating business knowledge on which managers base their actions will diminish as managers combine it with other sources of data (Bhimani and Willcocks, 2014).

The ability to analyse data about entire populations instead of having to rely on samples has implications for the use of several management accounting techniques. For example, current inventory and asset valuation methods, depreciation methods and valuation of intangibles will become obsolete or will have to change in the near future as big data technology provides alternatives (Vasarhelyi et al., 2015, p. 386). Big data will also change organizational structures, capital structures and industrial networks. For example, virtual platform organizations coordinating manufacturing or trading networks will need new methods of cost analysis (Bhimani and Willcocks, 2014). Finally, advances in statistical forecasting techniques and access to external data could improve forecasting accuracy, leading to better estimates of resource use and costs and improving budgeting (Warren et al., 2015).

Big data technologies enable the use of data types such as video, audio and textual data in management accounting activities. This could mean new ways of controlling employee behaviour through the monitoring and analysis of real-time events, for example, monitoring voice patterns of customers in online sales calls and suggesting sales approaches for sales persons in real time, or interpreting facial expressions of browsing shoppers from video feeds to optimize customer service (Warren et al., 2015).

Access to real-time data, the possibility of working with population data instead of sample data, the increasing processing capability of statistical analytical tools and developments in visualization methods mean that managers can search for new patterns, correlations and links in data. This could affect the decision-making approaches of managers with access to such technologies. In decision-making theory (Cyert and March, 2007; March, 1991), information search, decision-making and action are sequential activities. When access to information is instantaneous, alternatives can be evaluated on the fly, and actions can test and compare alternatives in parallel. "The management of an organization embracing data analytics requires also a particular integration of decision making and action" (Bhimani and Willcocks, 2014, p. 480).

Furthermore, big data has the potential to radically alter the organization of the management accounting function. This springs from its potential long-term impact on organizational decision-making (Kitchin, 2014). Decision-making often focuses on identifying causes of events to infer relationships or predict future events. An example would be variance analysis, which focuses on identifying quantity and price-related causes of budget variances. Data-driven decision-making, on the other hand, focuses on relationships and patterns in data that can support actions, where the "why" becomes secondary. If a pattern exists and is stable over time, then managers can base decisions on it. An example would be whether data on buying behaviour shows a stable pattern over time; if so, the firm could base sales activities on this pattern without having to examine the underlying causes of the behaviour. An example would be when hurricane warnings produce consistent correlated spikes in the sale of flashlights and Pop-Tarts (actual example from Hays, 2004). While the firm can base sales initiatives on this information, the underlying reason for why more Pop-Tarts are being sold before a hurricane strikes is not necessarily relevant to the decision. Such changes in the decision-making process are a disruptive force that can fundamentally change management accountants' role in organizations, the use of accounting data and the organization of the accounting function. It implies that management accountants will increasingly have to share responsibility for traditional management accounting analysis, such as profitability analysis for product and customer mix decisions, outsourcing decisions, capital budgeting valuations, stock optimization and incentive system design with other functions. On the other hand, decisions in other functions will also be affected as accounting data becomes broadly accessible through BI&A solutions. Thus, decisions on marketing campaigns, employee developments, and production maintenance could benefit. The management accounting function might even become integrated in a broader analytical function in the organization, together with customer analytics, process analytics and environmental analytics (Phillips, 2013).

In some of the big data literature, data quality is downplayed as a variable, because when data sets grow larger, cleaning data becomes unpractical and the importance of correct registration of any one piece of data is insignificant compared to the whole (Mayer-Schönberger and Cukier, 2013). This goes against the grain of accounting practice, where data quality assurance is at the core of, e.g., internal controls and management reporting. However, visual analysis tool implementations often work directly on transaction databases without data warehouses (Troyansky et al., 2015). There is no data staging or data clean up before analysis is performed. This is also at the heart of the "in memory" technologies that are currently being promoted, where transaction registration and data analysis are performed within the same database structure (Word, 2014). Working with "raw" data in reporting means data quality issues become increasingly important, especially to those who are responsible for management reporting. However, this has not been explored much in an accounting context. A related issue is the shift from "data ownership" to "data access" and its implications for management accounting. A key issue for analytical success is not how much data the organization owns but how much data it can access. This has implications for the role of management accountants as "curators" of accounting data. Because people in more functions would like to access accounting data and combine it with other data, management accountants will have to become proficient with giving access to data and assisting in data combination.

Finally, big data could potentially impact the skill sets of management accountants. Although some think that accountants merely need to understand the potential of big data and data analysis and do not need to develop specialist technical expertise (Bhimani and Willcocks, 2014), others disagree (Payne, 2014), seeing big data as a paradigm shift where accountants need to acquire new skills to be able to support decision making in the future.

4.3.2. Research gaps

While studies have put substantial effort into conceptualizing and defining big data in the context of IT research (Goes, 2014; Kallinikos and Constantiou, 2015; Woerner and Wixom, 2015; Loebbecke and Picot, 2015) and accounting (Bhimani and Willcocks,

2014; Vasarhelyi et al., 2015), its implications for the accounting profession (Warren et al., 2015), individuals, organizations and society are much less understood (Lycett, 2013; Zuboff, 2015). There are calls for more research into what creates success when utilizing big data in companies. What technological, organizational and environmental factors affect big data utilization and the subsequent value creation for the organization?

Specifically, there are calls for increased research into both incremental and disruptive changes in business models due to the use of big data and the effects of these changes on business organizations. Examples include how companies are monetizing data and how automatization changes value delivery. The consensus is that big data has the potential to change – and, in fact, is in the process of changing – business value creation through what is called dematerialization, density and liquification (Lycett, 2013). Companies are increasingly separating information aspects from physical products and then manipulating and recombining them in different contexts that create business value. Big data means more sources and types of usable data, and big data analytics enables new and improved insights into and predictions of business stakeholder behaviour. This, in turn, improves and disrupts business models when new actions and sources of value become possible (Woerner and Wixom, 2015). Management accountants will have to adapt to new forms of business models and business processes to be able to conduct effective value chain analysis.

Future trends in big data research will draw on the rise of social media, mobile computing and the merging of data warehousing with knowledge management. Specifically, social media and mobile computing have changed the decision context, as organizational members can interact from anywhere and with parties outside the traditional barriers of organizations (Hosack et al., 2012). Applications of BI&A solutions in social media offer competitive analytics that help monitor customer-generated opinion about own products and services as well as those of competitors. Sentiment analysis of social media can provide comparative analysis and benchmarking, allowing organizations to gather critical marketing intelligence. Although access to detailed competitor data is difficult, new business analytical techniques can work with limited and aggregate data that may accurately predict competitive intelligence. Thus, next-generation dashboards would benefit from integrating competitive measures, which would enhance customer relationship management and product and service strategies (Zheng et al., 2012).

Clearly, big data presents a new opportunity for management accountants to play an active role in data creation and decision support. Management accountants who have business acumen may be in a good position to specify and select data to promote easy discovery and retrieval (Madnick et al., 2009) while pointing out spurious correlations in big data. If “correlation trumps causation”, crowd wisdom is made equal to expert opinion; and if suggestions and predictions of opaque algorithms have significant effect on behaviour of managers and customer, then decision-making, like never before, will require sound human judgment (Quattrone, 2016). But how ready are management accountants to embrace such roles, and what capabilities and skills are required to successfully fulfil these new roles? This is an important research topic that has not been addressed adequately.

Moreover, with big data and better analytical techniques, organizations can better evaluate the performance of employees through process mining (Van der Aalst, 2014) website traffic activity and other behaviour captured thorough various sensors. To what extent do such new capabilities lead to better performance, and beyond what point are they likely to be destructive and adversely affect motivation? This is line with calls for studying how big data and digitalization could change the practice of democracy, invade privacy and create new forms of social structures. Furthermore, there is the question of how big data is used to predict and modify human behaviour through social media interactions and real-time adjustments of service offerings (Lycett, 2013; Zuboff, 2015) as a means to produce revenue and market control (Ford, 2016). There is thus a need to study the potential negative aspects of big data. For example, an understanding is needed of how the increased use of automatization in production as well as use of artificial intelligence and algorithms will impact the labour market and particularly the accounting profession. There are signs that this impact could cause a disruption that would surpass similar past disruptions, including the agricultural and industrial revolutions (Ford, 2016).

Research is also needed to study the changing roles of management accountants and the decentralization of the management accounting function. How will advanced self-generated reporting capabilities affect the future role of management accountants? How will management accounting incorporate new analytical possibilities and techniques? What new competencies are required from hybrid accountants as they are increasingly required to participate in and champion BI&A implementations (CIMA, 2016a; IMA, 2015)?

Research efforts will also benefit from a greater focus on big data-based predictive analytics as opposed to descriptive analytics. Predictive analytics has many uses, including theory testing and the comparison of competing models, in addition to predicting likely future outcomes. Most IS research develops models with explanatory power, which does not imply predictive power, as the two concepts do not equate (Shmueli and Koppius, 2011).

Finally, there is a need to apply different theoretical lenses to the changes being wrought by big data and digitalization to fully understand the impact and direction of change. This includes theories used in management accounting, such as institutional theory and dynamic capabilities theory as well as more-specific theories such as IT governance theory.

4.4. Use and satisfaction with BI&A in MA contexts

4.4.1. Current research focus

The review identified four articles that dealt with perceptual and behavioral aspects of BI&A use and its effects on decision-making and performance. Interestingly, the reviewed studies all used different research methods, namely an experimental design (Lee et al., 2008), surveys (Elbashir et al., 2013; Hou, 2012), a case study (Deng and Chi, 2012), and organizational archival data (Eldenburg et al., 2010). These studies mainly focused on what factors affect the successful use of BI&A in organizations – including the accounting function.

According to the reviewed studies, users' level of expertise (Lee et al., 2008), satisfaction (Hou, 2012), and the technical problems they encounter (Deng and Chi, 2012) affect system use and the decision quality.

Specifically, research shows that experts who are more efficient and effective in executing tasks compared to novice users deploy strategies that are more accurate and require less information processing (Hung, 2003). Thus, Lee et al. (2008) find that BI&A users perceive and use the system differently depending on their level of system expertise, although the level of system expertise does not affect decision performance. This may have implications for the design of BI&A in management accounting. Users with a high level of system and task expertise as opposed to novice users with little task experience perceive the system as being less restrictive. Also, novice users abandon system functions more often than more-experienced users, which indicates that novice users are more restricted by the system. However, although expert users have more-efficient and more-focused planning and problem solving behaviors, it is task expertise as opposed to decision support system expertise that affects decision quality.

An important construct in the information systems literature is “user satisfaction”, as it represents ‘success’ and indicates system use (e.g., Doll and Torkzadeh, 1988; Delone and McLean, 2003). Consistent with Torkzadeh and Dwyer (1994) and Lee et al. (1995), Hou (2012) suggests that there is a two-way positive relation between BI&A tool user satisfaction and usage frequency and duration. Furthermore, both BI&A tool satisfaction and usage have a positive effect on user performance in terms of decision-making efficiency and effectiveness – including users of BI&A technologies in management accounting. The success of BI&A is also affected by user access quality (Işık et al., 2013), although the impact of data quality on BI&A use or success is less understood (Popovič et al., 2012; Işık et al., 2013).

There is evidence that system ownership by non-accountants affects system use (Shields, 1995). Thus, when non-accountants participate in the design and implementation of an accounting information system (and, arguably, a BI&A system), they pay more attention to the system when making financial decisions (Eldenburg et al., 2010). This leads to better use of the system and its success due to better resource allocation.

Many problems are associated with implementing a new information system such as BI&A. A case study by Deng and Chi (2012) in the context of BI&A use in finance and supply chain management identifies seven problem areas and causes: reporting, data, workflow, role authorization, users' lack of knowledge, system error, and user–system interaction. Reporting and data problems ranked highest at both the initial and continued usage phases, suggesting that becoming familiar with the system's functionality was essential in resolving these issues.

Finally, it does not suffice to adopt a new system including BI&A; rather, organizations need to ensure that the system is used effectively and that they are integrated into decision-making processes (Popovič et al., 2012). There is no guarantee that BI&A will be successfully implemented, as resource owners may not be involved in the process. Thus, BI&A-supported strategies may need new governance structures and roles for better asset orchestration capability (Sharma et al., 2014). Also, BI&A are criticised for being too passive. Situated systems for decision support are complete solutions in the sense that they are active: they can continuously sense the environment, suggest actions, support the implementation of the decision and provide subsequent monitoring. A study by Vahidov and He (2010) provides evidence for the superiority of such solutions compared to conventional decision support systems in a personal finance context (Vahidov and He, 2010). Management accountants in this respect can become champions in promoting the integration of BI&A into decision-making.

4.4.2. Research gaps

First, BI&A solutions are increasingly being delivered via a cloud-computing infrastructure that requires speedy connection and disconnection to facilitate secure communication between network actors (Collins et al., 2010; Delen and Demirkan, 2013; Demirkan and Delen, 2013). Cloud computing is a fertile ground for future research, especially from the access and usability perspective, since the success of BI&A depends on the quality of user access, the level of integration of BI&A with other applications, and analytical capabilities (Işık et al., 2013; Popovič et al., 2012). Loosely coupled, discoverable, reusable and interoperable services will facilitate sharing of information and analytical models across organizations (Delen and Demirkan, 2013) that may very well include the sharing of management accounting models and analytical tools. The challenges of BI&A in cloud computing relate to security risks, integration, failure, and affordability.

On the whole, there is relatively little knowledge on how BI&A-enabled management accounting is affecting the behaviour of management accountants, managers and employees. For BI&A to have an impact on behaviour, organizations need to be able to assimilate it (Elbashir et al., 2013). Furthermore, as various technology acceptance theories would suggest that users, including management accountants, would have to be satisfied with the BI&A system to use it effectively. This may be especially relevant for BI &A systems, which may be difficult to use if rich in features, and because of the variety of algorithms used to mine multidimensional quantitative and qualitative data. Testing user satisfaction in the Information System domain has a long history, but little is known specifically about management accountants' user satisfaction with BI&A system use, what affects it and how that impacts outcome. IS research has shown that higher user satisfaction leads to improved system use and improved decision quality. Furthermore, a lack of usability may restrict the user and undermine the decision at hand. The presentation format and system feedback, which were discussed earlier, will no doubt influence satisfaction. Additionally, as with every IS, data quality and technical problems will certainly and adversely affect system use. Nevertheless, the success of the system is contingent on both the system itself and on user's knowledge of the system. Thus, user training of BI&A functionality in management accounting is essential (Deng and Chi, 2012). Exploring this in the context of management accounting seems an important research topic given the importance of management accounting in decision making.

Organizational decision processes are often non-routine, ill-structured and usually entail ambiguity and uncertainty. Studies emphasize the importance of flexibility in BI&A. According to Işık et al. (2013), BI&A success depends on system flexibility and the

extent to which it supports managing risk. The flexibility and adaptability of a BI&A system are also important characteristics because there may be conflicting requirements from analysts and decision makers (Kowalczyk and Buxmann, 2015). Because decision tasks in management accounting are often unstructured and non-routine, the innovative use of BI&A tools in supporting such decisions is an interesting research topic. Users can use IT systems in routine or innovative ways. However, it is when they are used routinely and innovatively simultaneously that significant advantages are created. Motivational factors play a role in how systems are utilized. Specifically, extrinsic and intrinsic motivations affect post-acceptance use of BI&A systems, where personal innovativeness with IT plays an important role as a moderator (Li et al., 2013). Thus, how can intrinsic motivation be cultivated? Also, do organizations need to increasingly employ management accountants with a stronger personal innovativeness with IT (Li et al., 2013)? Given that these qualities are important in using systems more innovatively, what training programs and HR strategies are required? How can a learning culture be fostered? Furthermore, even though technical issues affect BI&A use, many problems in relation to their use are caused by users' lack of knowledge of the system. Therefore, tracking system problems over an extended period can help improve user-training strategies (Deng and Chi, 2012).

On the other hand, it is ultimately task experience that is decisive in making high-quality decisions rather than experience with the BI&A system (Lee et al., 2008). Therefore, as various reports and papers to date suggest, it is crucial that management accountants continue to develop their strategic, analytical, and technological skills if they are to become strategic partners with management (Kavanagh and Drennan, 2008; Pathways Commission, 2012). Additionally, because BI&A systems are data intensive, data literacy skills will be highly valuable. How this is to be achieved and how it will impact the management accounting profession and potentially change the competency profile of management accountants are worthwhile topics to explore.

4.5. BI&A and data quality

4.5.1. Current research focus

Only two studies focused on data quality issues regarding the use of BI&A technology that could be related to management accounting. The question these two studies address is what are the dimensions of data quality regarding its fitness-for-use in decision-making?

Whereas Neely and Cook (2011) reviewed 15 years of data quality research in accounting, Bai et al. (2012) model optimal quality control policies to mitigate data quality-related risks in accounting information systems including BI&A. Data quality is essential for the accounting information system and consists of 15 dimensions: accuracy, believability, objectivity, reputation, value-added, relevancy, timeliness, completeness, appropriate amount of data, interpretability, ease of understanding, representational consistency, concise representation, accessibility, and access security (Wang and Strong, 1996). Dimensions of quality often require trade-offs, and certain dimensions may be more important than others, depending on the context. For example, the accuracy of financial statements may be more important for investors, whereas timeliness (e.g., demand data) may be more valuable in other contexts.

The literature on data quality can be grouped into three categories: governance, operation, and technology (Neely and Cook, 2011). Data governance is particularly important when organizations increasingly incorporate internal and external data sources into planning, control and decision-making. Data and information governance require plans, policies and procedures to ensure legal and ethical compliance. This involves personnel management in terms of increasing awareness of data-related issues and employee training (Neely and Cook, 2011). With the adoption of cloud-based BI&A, compliance and security risks are becoming even more prominent, as additional vulnerabilities are introduced with the changing location of the data (Yigitbasioglu, 2015). The second data quality category, operations, relates to the production, distribution and assurance of data. Finally, technology captures measurement, system design, information products (e.g., reports), and decision making, where the latter addresses the ability of the end-user to extract the data from the system in a meaningful and useful way.

Approaches to data collection in companies have also been studied. These approaches seem to vary depending on whether the overall purpose of the BI&A application is to gain insights, achieve consistency or foster transformation (Ramakrishnan et al., 2012). Companies are more likely to develop enterprise-wide data warehouses if the BI&A application is aimed at creating consistency or transformation rather than insight, where the latter goal might present challenges from a DQ point of view, as data would be more comprensive, less structured and potentially in real time.

4.5.2. Research gaps

Although external auditors' perception of cloud computing benefits and risks are known to some extent (Yigitbasioglu, 2015), little is known about its implications for data quality, given its criticality in the use of BI&A (Popovič et al., 2012). With the proliferation of BI&A solutions through new paradigms such as cloud computing, data quality (DQ) becomes an important topic for practice and research. As data volumes increase and more types of data are included in BI&A systems, challenges regarding accuracy, reliability, consistency, completeness, and verifiability emerge and new methods are needed to assess and improve data quality for decision making (Clarke, 2015).

When it comes to BI&A and management accounting, it seems that data quality has – to use the terminology of Neely and Cook (2011) - two dimensions. One refers to MA tasks such as measurement of performance and ensuring compliance, where the usual criteria of data accuracy, validity, comprehensiveness and reliability apply. The other refers to decision support, where timeliness and “fitness for use” are of primary importance. Decision makers need information on short notice, often in real time and with a brief window within which to make decisions. Moreover, the information can be based on vast data sets in different formats from a variety of data sources. In this context, it is practically and economically impossible to ensure that the data conforms to usual data quality criteria. Ensuring that the data can be accessed, manipulated, and structured is critical. Furthermore, it is important that different

analytical methods and tools can be brought to bear and that the results can be visualized throughout the process. An important research topic is how this development affects the role of the management accountant. Are management accountants becoming replaced by data scientists when it comes to decision support? How will this development affect the organization of the management accounting function? Should management accountant scholars be focusing on developing new management accounting techniques that encompass statistical analytical methods? Moreover, consistent with past accounting research, Neely and Cook (2011) suggest that accounting research in the future should focus on the fitness-for-use of information for effective decision-making, which includes areas such as visualization of data and is covered elsewhere in the paper. Management accountants might have to be involved in assessing data quality in terms of defining the costs of low data quality as well as assessing the organization's DQ (Woodall et al., 2013). In the same vein, work could focus on how DQ can be visualized for users to improve decision making (Price and Shanks, 2011).

4.6. Summary of themes, gaps and research questions

Based on the broad themes identified in the literature review, several potential research questions are presented below. Whereas some of the research questions were derived from the analysis and synthesis of the literature, others were proposed by the authors of the reviewed papers. These gaps and opportunities may direct future researchers and can therefore support with the advancement of knowledge in this growing field.

5. Concluding discussion

This study reviewed over 60 papers to evaluate the literature on the relationship between MA and BI&A. It critically reviewed and evaluated the volume and content of this literature and highlighted research gaps and opportunities for future research.

While BI&A can potentially and dramatically affect the overall role of management accountants' tasks and techniques (CIMA, 2016a, 2016b; IMA, 2015), the general conclusion is that a relatively low number of papers focus on applications of BI&A in management accounting. Many papers are conceptual and do not address key tasks in management accounting. With some exceptions, there seems to be limited interest in the management accounting community in generating knowledge within this domain. The conclusion of this review must be that Granlund's reservations that “our current understanding of these developments in the accounting academia is very limited” are valid (Granlund, 2011, p. 10). This is worrying, given the potential impact BI&A technology is predicted to have on decision support and decision making in organizations.

Comparing the themes identified in the first review of the IS literature with those identified in the accounting literature, there seems to be relatively little cross-fertilization between the two fields. For example, there is considerable research in the IS field focusing on infrastructure and data quality but relatively little focus in the AIS field when it comes to BI&A. Also, research in the IS field on what affects the success of IS implementations has a long history, while these explorations are relatively limited in the AIS literature focusing on BI&A. Conversely, when it comes to visualization and data delivery, there is limited focus in the IS literature on the impact of BI&A on decision making processes and quality, while this topic attracts considerable interest in the accounting literature. More cross-functional projects where AIS and IS researchers cooperate seem rare but would offer fruitful avenues for future research combining AIS and IS competencies and focus.

Of the limited number of studies that have been published, none have adopted a critical research perspective (Arbnor and Bjerke, 2008; Burrell and Morgan, 1979; Lincoln et al., 2011). The papers on big data for example reflect an optimistic view, focusing mainly on the opportunities inherent in this development. However, some of the descriptions in these papers of potential applications of big data technology are worrying, considering privacy concerns, data security, micro-management of employees, stifling of employee creativity and potential negative behavioral effects (Warren et al., 2015). One of the potential effects of digitalization and increased automatization is loss of jobs, including within the accounting domain (Ford, 2016). How will these trends affect the jobs of management accountants? The impact of big data on personal freedom, choice and democracy indicate that there are several aspects that management accountants need to be aware of (Zuboff, 2015). These issues need to be explored further using critical theories and approaches, as has been done, for example, within the ERP domain (Dillard et al., 2005; Dillard and Yuthas, 2006).

Another aspect of existing research is that there is relatively little anchoring in existing theory. There are various theories that could be fruitful in studying BI&A in management accounting. Old institutional theory, for example, has been used in the literature to study management accounting change (Burns and Scapens, 2000). This theory has been applied within the context of ERP systems with interesting results (Quattrone and Hopper, 2001) and could be used to study how BI&A is institutionalised into routines of management accounting tasks in organizations. Also, the dynamic capabilities view of the firm (Teece et al., 1997) may provide an alternative lens to study how organizations reconfigure their resources to leverage BI&A technologies in management accounting for competitive advantage (see Table 5 for examples of research questions). One of the benefits of using established theory is that it often focuses on mediating and moderating variables and how they affect the research variables. For BI&A and management accounting, this could include external environment variables such as legislation, economic environment, national culture competition and customer and supplier relations (Chenhall, 2003; Ewusi-Mensah, 1981). Internal variables could include size, industry, organizing principles, power relations, organizational culture and management characteristics (Chenhall, 2003; Chenhall and Chapman, 2006). Finally, very few studies focus on what outcomes BI&A applications in management accounting lead to. These outcomes could be aspects of organizational performance as well as changes in decision quality, resource use, and perceptions of managers.

Another area to focus on could be accounting education, particularly at universities. Given the lack of papers on accounting education, there is a need to re-evaluate accounting curricula given the actual and potential impact of BI&A and big data on

Table 5
Examples of research questions regarding BI&A and management accounting.

Themes	Research gap	Examples of research questions
Information delivery and system feedback for management accounting tasks	A better mapping of appropriate visualization techniques supporting MA tasks is required, backed with empirical evidence.	1. What visualization techniques for qualitative data are appropriate for MA decision support tasks? 2. What visualization techniques are required for more-advanced analytical techniques for planning and control? 3. Which decision contexts and tasks require what types of features, and will they improve decision making? 4. Which management accounting tasks require more interactivity, prompts, and recommendations in the supporting BI&A solution? 5. How do performance dashboards and other visualizations affect the motivation, performance and behaviour of employees? 6. What should be the future role of the management accountant in terms of supporting information delivery in organizations?
BI&A to improve MA tasks and techniques	More empirical evidence is needed to identify what areas of MA (tasks and techniques) are improved through BI&A and what skills and organizational capabilities are required to institutionalise BI&A.	1. How does BI&A support inference, prediction and assurance in management accounting tasks? 2. How can management accountants ensure – through the use of BI&A - that data to insight is effectively turned in to decision to value? 3. What should be the responsibilities of management accountants in BI&A technology application? Are more-focused roles within management accounting required? 4. How does BI&A impact less-used MA techniques such as zero-based budgeting or scenario and contingency planning? 5. How does BI&A enable better control? 6. Will some MA techniques become obsolete due to real-time data from customers and through the internet of things?
Big data impact on management accounting	The application of qualitative (in particular case-studies) and quantitative methods would be useful to demonstrate how big data is used in MA.	1. How do big data-based analytical techniques using external data affect revenue and cost forecasting? 2. How do increased access and volume of internal and external data affect the performance of management accounting tasks? 3. What new competencies are becoming necessary in the combination of skills and competencies that form the management accounting function? 4. What will be the impact of data scientists and new statistical techniques on the traditional management accountant role? 5. How will new analytical techniques based on employee big data affect employee motivation?
Use and satisfaction with BI&A in MA contexts	More research is needed to identify factors that improve BI&A use in organizations for various user types and to implement effective BI&A-related governance mechanisms.	1. To what extent are management accountants satisfied with BI&A? 2. What features or characteristics of BI&A drive user satisfaction of management accountants? 3. How can management accountants be better motivated to use BI&A tools more innovatively? 4. To what extent should BI&A tools take into account the expertise of the end user? 5. What training and HR strategies are required to ensure effective use of BI&A in management accounting? 6. What governance structures are needed to switch to an analytics-based management accounting culture? 7. How is the management accounting function being impacted by growing analytical and decision support competencies in other organizational functions? 8. How can management accountants help create an analytical decision-making culture? 9. How is the increasing virtualization of organizations impacting the organization of management accounting? 10. What are the benefits and risks of adopting cloud-based BI&A solutions for management accounting? 11. What kinds of opportunities exist in management accounting for cloud-based BI&A?
BI&A and data quality	Data quality in MA is under-researched, as evident from the lack of papers in this area.	

(*continued on next page*)

Table 5 (*continued*)

Themes	Research gap	Examples of research questions
		1. Which data quality attributes are more important for the management accounting function, e.g., accuracy or breadth? 2. How does data quality impact the use of BI&A tools? 3. How can the costs/benefits of data quality be quantified?

accounting. Several organizations, such as AACSB and PwC, have been stressing the need to introduce analytics early on to accountants during their first degree where courses on IT and analytics seem to be merely optional (AACSB, 2014; PwC, 2015). Research is lacking on the current progress in this field. The question is how should accounting education respond to increasing use of BI&A by accountants? Should BI&A subjects become increasingly mandatory in accounting curricula?

The method used for the review in this study has some limitations. First, only high-quality journals were included in the review, which left out papers in lower ranked journals. The selection of only high ranked journals for the review also risked omitting highly cited papers published elsewhere. To address this limitation, we carried out an explorative search in Google Scholar for papers with more than 100 citations (West and Bogers, 2014) for years 2005–2015. Only one new additional paper was identified that fit all the criteria. The paper was included in the review.

Another limitation relates to the keywords used in the search, which were not exhaustive, although great care was taken to include the most relevant terms. Furthermore, the search was limited to the period 2005–2015. Nevertheless, with over 60 papers in the IT and accounting domains, we believe that the review included the most relevant and influential literature.

If AIS research is to remain relevant to practice and academia, it must be agile in its research focus. When enterprise systems emerged in the early 90s, they became an important focus area of AIS research (Sutton, 2010), and today, they have a relatively well-defined research agenda (Grabski et al., 2011). Similarly, applications of information technology and analytical methods in continuous auditing and monitoring have been researched for decades (AICPA, 2015; Vasarhelyi et al., 2004; Vasarhelyi and Halper, 1991). Fortunately, there is some impetus towards researching BI&A and MA, and we very much welcome recent papers, especially in the MA field, including Appelbaum et al. (2017), where the Managerial Accounting Data Analytics Framework is developed, and Peters et al. (2016), who provide evidence on BI&A's impact on management control and competitive advantage. There is a need to continue this positive development and we hope that our paper will inspire more research in this area.

Appendix 1. Number of papers in academic IS/IT journals addressing BI&A

Journals (rating)	Number of papers (2010–2015)
Decision Support Systems (A*)	6
European Journal of Information Systems (A*)	4
Information and Management (A*)	4
Information Systems Research (A*)	2
Journal of Management Information Systems (A*)	4
Journal of Information Technology (A*)	5
Journal of the Association for Information Systems (A*)	2
Journal of Strategic Information Systems (A*)	2
Management Information Systems Quarterly (A*)	3
Total	**32**

Appendix 2. Overview of articles addressing BI&A and management accounting, organized by research theme[a]

Research theme	Author (s)	Title	Year	Journal	Research method	Theory
Information delivery and system feedback for management accounting tasks	Locke, Lowe, Lymer	Interactive Data and Retail Investor Decision-Making: An Experimental Study	2015	Accounting and Finance	Experiment	Cognitive load theory
	Chen, Jeremias, Panggabean		2015	Journal of Accounting Research	Experiment	Attention and cognitive load theories

		The Role of Visual Attention in the Managerial Judgment of Balanced-Scorecard Performance Evaluation: Insights from Using an Eye-Tracking Device				
	Tang, Hess, Valacich, Sweeney	The Effects of Visualization and Interactivity on Calibration in Financial Decision-Making	2014	Behavioral Research in Accounting	Experiment	Calibration and dual coding theory
	Dilla, Janvrin, Jeffrey	The Impact of Graphical Displays of Pro Forma Earnings Information on Professional and Nonprofessional Investors' Earnings Judgments	2013	Behavioral Research in Accounting	Experiment	Cognitive fit theory
	Yigitbasioglu & Velcu	A Review of Dashboard in Performance Management: Implications for Research and Practice	2012	International Journal of Accounting Information Systems	Conceptual	No particular theory
	Seow	The Effects of Decision Aid Structural Restrictiveness on Decision-Making Outcomes	2011	International Journal of Accounting Information Systems	Experiment	Search of Associative Memory theory
	Cardinaels E, van Veen-Dirks	Financial versus Non-financial Information: The Impact of Information Organization And Presentation in A Balanced Scorecard	2010	Accounting, Organizations and Society	Experiment	No particular theory
	Mascha & Smedley	Can Computerized Decision Aids do 'Damage'? A Case for Tailoring Feedback and Task Complexity Based on Task Experience	2007	International Journal of Accounting Information Systems	Experiment	Theory of technology dominance
	Dilla, Janvrin, Raschke	Interactive Data Visualization: New Directions for Accounting Information Systems Research	2010	Journal of Information Systems	Literature review	No particular theory
	Peng, Viator, Buchheit	An Experimental Study of Multidimensional Hierarchal Accounting Data: Drill-Down Paths Can Influence Economic Decisions	2007	Journal of Information Systems	Experiment	Concept of satisficing behaviour
BI&A to improve MA tasks and techniques	Schneider, Dai, Janvrin, Ajayi, Raschke	Infer, Predict, and Assure: Accounting Opportunities in Data Analytics	2015	Accounting Horizons	Conceptual	No particular theory
	Kowalczyk & Buxmann	An Ambidextrous Perspective on Business Intelligence and Analytics Support in Decision Processes: Insights from a Multiple Case Study	2015	Decision Support Systems	Case study	Concept of ambidexterity
	Sharma, Mithas, Kankanhalli	Transforming Decision-Making Processes: A Research Agenda for Understanding the Impact of Business Analytics on Organizations	2014	European Journal of Information Systems	Conceptual	No particular theory
	Vukšić, Bach, Popovič	Supporting Performance Management with Business Process Management and Business Intelligence: A Case Analysis of Integration and Orchestration	2013	International Journal of Information Management	Interviews	Concept of orchestration
		Improving Performance Aligning Business Analytics with Process Orientation	2013	International Journal of Information Management	Survey	No particular theory

	Bronzo, de Resende, de Oliveira, McCormack, de Sousa, Ferreira					
	Elbashir, Collier, Davern	Measuring the Effects of Business Intelligence Systems: The Relationship Between Business Process and Organizational Performance	2008	International Journal of Accounting Information Systems	Survey	No particular theory
	Elbashir, Collier, Sutton, Davern, Leech	Enhancing the Business Value of Business Intelligence: The Role of Shared Knowledge and Assimilation	2013	Journal of Information Systems	Survey	Theory of IT assimilation
	Elbashir, Collier, Sutton	The Role of Organizational Absorptive Capacity in Strategic Use of Business Intelligence to Support Integrated Management Control Systems	2011	The Accounting Review	Survey	Concept of absorptive capacity
	Petrini and Pozzebon	Managing Sustainability with The Support of Business Intelligence: Integrating Socio-Environmental Indicators and Organizational Context	2008	Journal of Strategic Information Systems	Interviews	No particular theory
	Marx, Wortmann, Mayer	A Maturity Model for Management Control Systems - Five Evolutionary Steps to Guide Development	2012	Business & Information Systems Engineering	Conceptual	No particular theory
Big data's impact on accounting	Warren, Kevin, Moffitt, Byrnes	How Big Data Will Change Accounting	2015	Accounting Horizons	Conceptual	No particular theory
	Vasarhelyi, Kogan, Tuttle	Big data in Accounting: An Overview	2015	Accounting Horizons	Conceptual	No particular theory
	Bhimani & Willcocks	Digitisation, 'Big Data' and the Transformation of Accounting Information	2014	Accounting and Business Research	Conceptual	No particular theory
	Payne	Discussion of 'Digitisation, 'big data' and the Transformation of Accounting Information' by Alnoor Bhimani and Leslie Willcocks (2014)	2014	Accounting and Business Research	Conceptual	No particular theory
Use and satisfaction with BI&A in MA contexts	Hou	Examining The Effect of User Satisfaction on System Usage and Individual Performance with Business Intelligence Systems: An Empirical Study of Taiwan's Electronics Industry	2012	International Journal of Information Management	Survey	Concept of user satisfaction
	Deng & Chi	Understanding Postadoptive Behaviors in Information Systems Use: A Longitudinal Analysis of System Use Problems in the Business Intelligence Context	2012	Journal of Management Information Systems	Archival	No particular theory
	Eldenburg, Soderstrom, Williams, Wu	Behavioral Changes Following the Collaborative Development of an Accounting Information System	2010	Accounting, Organizations and Society	Case study	Concept of participation
	Lee, Wagner, Shin	The Effect of Decision Support System Expertise on System Use Behaviour and Performance	2008	Information and Management	Experiment	No particular theory
BI&A and data quality	Bai, Nunez, Kalagnanam	Managing Data Quality Risk in Accounting Information Systems	2012	Information Systems Research	Conceptual	No particular theory

Neely & Cook	Fifteen Years of Data and Information Quality Literature: Developing a Research Agenda for Accounting	2011	Journal of Information Systems	Conceptual	No particular theory

[a]Does not include the one highly cited paper from Google Scholar.

Appendix 3. List of journals

Accounting journals

1. Abacus
2. Accounting and Business Research
3. Accounting and Finance
4. Accounting Auditing and Accountability Journal
5. Accounting Horizons
6. Accounting, Organizations and Society
7. Behavioral Research in Accounting
8. British Accounting Review
9. Contemporary Accounting Research
10. Critical Perspectives on Accounting
11. Foundations and Trends in Accounting
12. International Journal of Accounting Information Systems
13. Issues in Accounting Education
14. Journal of Accounting and Economics
15. Journal of Accounting and Public Policy
16. Journal of Accounting Auditing and Finance
17. Journal of Accounting Literature
18. Journal of Accounting Research
19. Journal of Business Finance and Accounting
20. Journal of Contemporary Accounting and Economics
21. Journal of International Accounting Research
22. Journal of Management Accounting Research
23. Management Accounting Research
24. Review of Accounting Studies
25. The Accounting Review
26. The European Accounting Review
27. The International Journal of Accounting

IS/IT journals

1. Australasian Journal of Information Systems
2. Behaviour and Information Technology
3. Business & Information Systems Engineering
4. Communications of the ACM
5. Communications of the Association for Information Systems
6. Data and Knowledge Engineering
7. Data Base for Advances in Information Systems
8. Decision Support Systems
9. Enterprise Information Systems
10. European Journal of Information Systems
11. Group Decision and Negotiation
12. Human-Computer Interaction
13. Information and Management
14. Information and Organization
15. Information and Software Technology
16. Information Communication and Society
17. Information Systems Frontiers
18. Information Systems Journal
19. Information Systems Research

20. Information Technology and People
21. International Journal of Cooperative Information Systems
22. International Journal of Electronic Commerce
23. International Journal of Information Management
24. International Journal of Law and Information Technology
25. Journal of Computer Information Systems
26. Journal of Global Information Management
27. Journal of Information Systems
28. Journal of Information Technology
29. Journal of Information Technology Theory and Application
30. Journal of Management Information Systems
31. Journal of Strategic Information Systems
32. Journal of Knowledge Management
33. Journal of Organizational Computing and Electronic Commerce
34. Journal of the American Society for Information Science and Technology
35. Journal of the Association for Information Systems
36. Knowledge Management Research and Practice
37. Knowledge-Based Systems
38. Management Information Systems Quarterly
39. MIS Quarterly Executive: a research journal dedicated to improving practice
40. Scandinavian Journal of Information Systems

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