Designing Attention-aware Business Intelligence and Analytics Dashboards

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Abstract. The design of user interface is known to influence the users' attention while they are interacting with applications such as Business Intelligence and Analytics (BI&A) dashboards. BI&A dashboards are considered as critical because they contain a lot of compressed information and managers only spend a little time to process the provided information. Thereby, they need to manage their visual attention properly due to inattentional blindness and change blindness issues. We propose to investigate the design of BI&A dashboards that are sensitive to the users' attention. So called attention-aware BI&A dashboards are of utmost importance in the field of BI&A systems since attention is known to play a major role in constructing decisions. We motivate our research project and present the initial design of attention-aware BI&A dashboards. Especially the inclusion of eye-tracking technology is an important aspect of our proposed design.

Keywords: Attention-aware · Eye-tracking devices · BI&A · Dashboards · Visual attention

1 Introduction

User interface (UI) design is known to influence attention of the users while they are interacting with applications [1]. The users' attention is assumed to be selective [2] as only a limited amount of visual information can be processed simultaneously [3]. There are two methods of directing attention while users are interacting with an UI, stimulus-driven and goal-directed selection [4]. In the stimulus-driven selection, the attention is guided by salient visual features, which make elements in the interface stand out from their neighbours and therefore grab the user's attention. In the goal-directed selection, the users' intention is considered and that users select specific parts of the interface consciously. However, even with a perfect UI design, users will allocate their attention differently, depending on their task, the environment, and the users' characteristics [5]. UIs that are sensitive to the users' attention are called attentive user interfaces [6] and managing the users' attention is one of the most pressing but also difficult challenges in human-computer interaction (HCI) research [7].

Business Intelligence & Analytics (BI&A) systems focus on supporting users in the decision making process. Specifically, BI&A dashboards refer to graphical UIs that contain analytical results and measures of the organization's business performance [8].

Such dashboards contain functional and visual features that support and enable managerial decision making [8]. The intersection of HCI and BI&A, such as designing proper BI&A dashboards, is considered as critical [9], because there is a lot of compressed information on them and managers only spend little time to process the presented information. On the one hand, using the powerful analytical capabilities and provided analytical results in BI&A dashboards promises to support decision makers. This is critical since including not enough information in a BI&A dashboard can make it useless and having relevant data that fits to the tasks of decision makers is crucial [10, 11]. On the other hand, processing such enormous amount of information is a difficult task for decision makers. A reason for that is the limitation of the capacity of humans to process visual information [12]. To cope with this limitation, decision makers process the vast amount of information provided in BI&A dashboards by using selective visual attention [13, 14] . Selective visual attention refers to the cognitive process in that decision makers are concentrating on the discrete aspect of analytical results on a dashboard while ignoring other parts. Simon [15] recognized that a wealth of information may create a poverty of attention. Thus, there is a need to allocate the decision maker's visual attention efficiently among the overabundance of information sources on a dashboard, since attention is known to play an important role in constructing decisions [16].

We propose to investigate the design of BI&A dashboards that are sensitive to the users' attention. So called attention-aware BI&A dashboards are of utmost importance in the field of BI&A systems, because of the constructing role of attention in human decision making. From a technological point of view, eye-tracking devices can be utilized for designing attention-aware dashboards. Visual attention is particularly relevant to attention-aware systems since the current predominant modality for computer-to-human communication is visual [17]. Researchers found that the users' eye movements can be used as an approximation for users' visual attention [18]. Moreover, eye movements can be used to approximate the users' cognitive processes and give a hint about what users are currently thinking or what their intentions are [19]. In addition to that, researchers in the IS domain suggest using these tools to design systems that reduce cognitive overload by enhancing the users' capabilities [20]. So far, there is only limited research examining BI&A systems and the related cognitive user states, despite their economic significance and widespread use [21]. Moreover, there is a lack of research in designing attention-aware BI&A dashboards. In our research, we focus on the design of attention-aware BI&A dashboards by applying a design science research (DSR) approach [22]. We specifically focus on the design of BI&A dashboards that are sensitive to the users' visual attention by analyzing their eye movement data. Summed up, our research project addresses the following overall research question:

> *How to design attention-aware BI&A dashboards in order to improve the individual performance of decision makers?*

Our research project will contribute by providing design knowledge for attention-aware BI&A dashboards. In this research in progress paper, we motivate this important research topic, outline the structure of our research project, and present the initial design for attention-aware BI&A dashboards.

2 Conceptual Foundations and Related Work

2.1 Business intelligence and analytics dashboards

BI&A systems are a well-known class of supportive systems for decision makers. They refer to the techniques, technologies, systems, practices, methodologies, and applications that analyze critical business data to help an organization understanding its business and market better as well as to make timely business decisions [23]. To support decision makers, BI&A systems are generating insights by utilizing analytical techniques and then visualizing the insights in the form of dashboards. The dashboards should be designed in a way to help decision makers to maintain their cognitive tasks such as decision making in convenient ways. Therefore, dashboards need to be evaluated according to their design features and the way the users interact with them to make decisions [8]. The interaction between decision makers and BI&A dashboard is mainly focused on investigating the information visualization [24]. In fact, the proper usage of the BI&A front-end (e.g. dashboards) and matching it to the decision makers' tasks are known to affect the success of such systems [25]. The design of dashboards is important and there is an ongoing discourse in research on how to design them properly [8].

2.2 Eye-tracking and attention

The users' attention is assumed to be selective [2] and researchers refer to attention as the set of processes enabling and guiding the selection of incoming perceptual information [17]. Measuring the users' attention, or an approximation of it, is possible by applying subjective and objective measurements [12, 26]. Researchers use eye-tracking devices in neuroscience, psychology, ergonomics, advertising, and design [27] as the users' eye movements can be used as an approximation of their visual attention [13] [18], their cognitive processes, and the users' intentions [19]. Eye-tracking devices record the users' eye movements when interacting with UIs, and this information can be used as input for intelligent UIs [28], such as attentive UIs [6]. Duchowski [29] distinguishes between interactive and diagnostic eye-tracking applications. Based on this categorization, interactive applications utilize eye-tracking for attentive interactions such as moving the cursor or selecting an object through individuals' eyes. On the other hand, diagnostic applications record the eye movements, and use this source of data as an evidence of the users' visual and attentional processes [29]. Lack of attention while working in the digital environments can cause different errors which are known as attentional breakdowns [30]. The eye movement data can be used for the design of attention-aware systems in order to support users to avoid or recover from attentional breakdowns. The failure to notice a fully visible, but unexpected content in UIs can be explained by the phenomenon named inattentional blindness. Failing to visually recognize an object can occur because of a lack of attention since this is a necessary precondition for visual perception [31]. Moreover, the ability to notice changes is important for users [32] and the inability to detect changes is called change blindness [33]. The phenomenon of change blindness has inspired strong claims about visual attention, visual

memory, and awareness [32]. Moreover, attention is important to support change detection [34]. The difference between change blindness and inattentional blindness is that inattentional blindness refers to missing information on one display at a specific point in time while change blindness refers to missing changes between related displays in different points of time.

3 Research Method

Our research project follows the DSR approach proposed by Kuechler and Vaishnavi [35] and is divided into two consecutive design cycles (see **Fig. 1**).

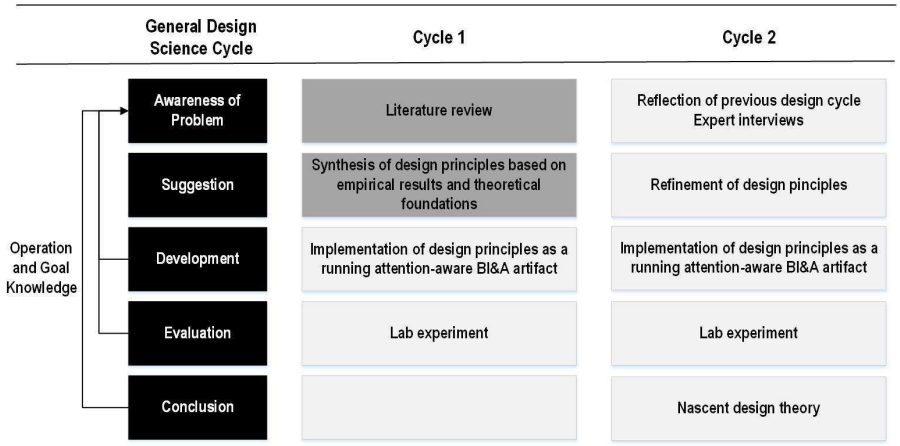

Fig. 1. Design cycles and research activities

In the first design cycle, we conducted a literature review on designing attention-aware UIs to get an overview on the topic and to identify research gaps. We identified the need to investigate the issue of missing important information because of attentional breakdowns, especially focusing on the two phenomena inattentional blindness [31] and change blindness [33]. Moreover, we identified the need to support BI&A dashboard users to manage their visual attention while using dashboards. The availability of new technology, such as affordable and reliable eye-trackers enables us to design an innovative solution to these issues. At the moment, we are in the suggestion phase of the first design cycle and identified initial meta-requirements for the design of attention-aware BI&A dashboards. Next, the meta-requirements will serve as the baseline for theory-grounded design principles. The derived design will be instantiated in the form of an attention-aware BI&A dashboard artifact that will be evaluated in a laboratory experiment.

In the second design cycle, we will start with the reflection of the previous design cycle's results and refine our design accordingly. In addition, we will conduct a series of expert interviews with BI&A dashboard users. In these interviews, we will discuss

our current findings and present the instantiated attention-aware BI&A dashboard artifact to receive feedback from them. We will use the interviews' results and additional theoretical knowledge to adapt our design. Subsequently, we will develop an improved attention-aware BI&A dashboard artifact based on the adapted design and conduct a second laboratory experiment evaluation. The findings of both experiments will serve as the baseline to derive a nascent design theory for attention-aware BI&A dashboards.

4 Attention-aware BI&A Dashboard Design

In the following, we discuss the current state of deriving meta-requirements for the design of attention-aware BI&A dashboards by focusing on missing important information on BI&A dashboards as an attentional breakdown [30]. BI&A dashboards and the included interactive technologies have the potential to bias decisions by focusing attention on a limited set of alternatives, increasing the salience of less diagnostic information, and encouraging inappropriate comparisons [11].What users see or do not see depends on how they allocate their attention while interacting with BI&A dashboards. Missing important information on BI&A dashboards can be approached by addressing the two phenomena inattation blindness [31] and change blindness [32]. Having a comprehensive overview of the presented information on BI&A dashboards and also notice changes from the past are essential for the decision makers. We especially include eye-tracking devices in our proposed design for BI&A dashboards, as eye movement data is an important aspect of the proposed solution to the addressed issues. First, we argue that an attention-aware BI&A dashboard should be able to capture the users' current visual attention. Thus, we propose our first meta-requirement (MR):

MR1: *Monitor the users' visual attention.*

There exist subjective as well as objective measurements for the users' visual attention. Researchers argue that the users' eye movements, as well as their current eye fixations, are an approximation for their visual attention and their cognitive processes [18, 19]. Eye-tracking technology can be used to detect the users' gaze position and collect the relevant eye movement data (such as fixation, saccade, etc.) in real-time. Based on this data, the users' visual attention can be analyzed. Thus, we propose the second MR:

MR2: *Utilize eye-tracking devices to collect users' eye movement data.*

Decision makers face the challenge to make biased decisions by focusing their attention on a limited set of alternatives on BI&A dashboards [11]. Having only a subset of the required information can result in inaccurate decision making. Providing feedback on their current visual attention can enable them to allocate their visual attention more efficient and avoid attentional breakdowns and miss important information [30]. Such feedback can direct users to allocate attention on missed important information and avoid inattentional blindness while investigating the BI&A dashboard. Moreover, having efficient attention allocation on the BI&A dashboard will support decision makers to compare the results and find the changes. Feedback refers to sending back information about what action has been done, and various kinds of feedback are available

for interaction design [36]. How and where users paid attention is known as a valuable source of information to provide feedback [37]. Thus, we propose the third MR:

MR3: *Provide feedback on the users' visual attention.*

Based on the three MRs, we propose a preliminary design as well as system architecture for attention-aware BI&A dashboard (see **Fig. 2**) in the following. Please note, as our design is not finalized yet, the presented design and system architecture is discussed only on an abstract level.

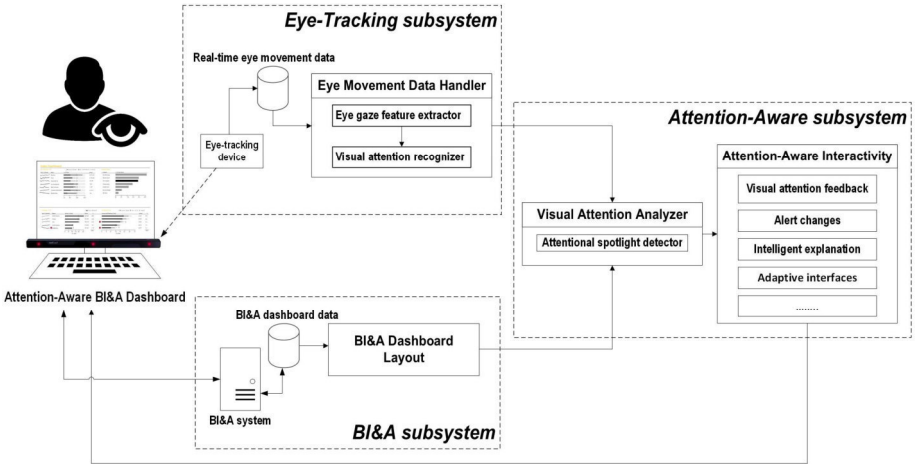

Fig. 2. Attention-aware BI&A dashboard system architecture

The proposed architecture includes the eye-tracking, BI&A, and attention-aware subsystems. The BI&A subsystem handles the relevant business data, data analysis, and visualizes the analytical results in the form of a BI&A dashboard. On the other hand, the eye-tracking subsystem is responsible for tracking the users' eye movements while interacting with the BI&A dashboard and stores the relevant eye movement data (such as fixation, saccades, etc.). This subsystem contains the "eye movement data handler" that is responsible for analyzing the real-time eye movement data and extracting the relevant information. This information is used to determine the users' visual attention. The attention-aware subsystem includes the "visual attention analyzer" component that merges the information from the "eye movement data handler" and the BI&A dashboard layout. It receives the gaze position from the eye-tracking subsystem and identifies the users' attentional spotlight in the BI&A dashboard. This component analyzes whether the decision maker missed some visible information or paid enough attention to the relevant content, determines the time to give feedback, and process the changed information, etc. The other component in this subsystem is the "attention-aware interactivity". Interactivity is the key IT's ability to affect cognitive processes and ultimately the performance of such systems [38]. This component implements and supports the attention-aware interaction between the decision maker and the BI&A dashboard. Each of these interactions can support decision makers in managing their visual attention in

an efficient way. An example of such interaction is “attention feedback” that provides real-time feedback to the decision makers about how they allocated their visual attention on the BI&A dashboard. Providing real-time feedback will help decision makers to reduce mental load and make the interaction easy [39]. Moreover, we argue that such attention feedback supports users to manage their visual attention in a better way. The current design is still work in progress and based on the provided information and MRs, there can be different attention-aware interactions.

5 Conclusion

This research in progress paper presents the motivation of our research project on the design of attention-aware BI&A dashboards. According to the classification by Gregor & Hevner [40] our research represents an improvement as we address an existing problem (support users to manage their visual attention) by combining eye-tracking devices and BI&A dashboards and providing the design of a new solution (attention-aware BI&A dashboards) [40]. Thereby, the research will contribute to research and practice by providing design knowledge for attention-aware BI&A dashboards. As next steps, we will finalize the design suggestion in the first design cycle and implement an artifact based on it. We will then evaluate this attention-aware BI&A dashboard artifact in a laboratory experiment with respect to the validity of the design as well as the effect on the users’ visual attention. In addition to the research activities planned for this research project, there are further opportunities for future research on this important issue. An attention-aware BI&A system is not limited to a feedback component. Instead, there are further attention-aware interactive elements such as guidance design features [41] to find changes, the provision of real-time explanations when users pay attention to the particular part of graphs, adaptive user interfaces based eye movement data, eye-based interactive information visualization, etc.

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