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Designing Attention-aware Business Intelligence and Analytics Dashboards to Support Task Resumption

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DESIGNING ATTENTION-AWARE BUSINESS INTELLIGENCE AND ANALYTICS DASHBOARDS TO SUPPORT TASK RESUMPTION

Research in Progress

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Abstract

External interruptions are a common phenomenon in today's working environment. Specifically, attentional shifts in working environments lead to task resumption failures that refer to the improper resuming of a primary task after an interruption and negatively influencing the individual performance of employees. Business Intelligence & Analytics (BI&A) systems are well recognized as an essential concept to support decision making of employees. One important and frequently used BI&A system component are dashboards. BI&A dashboards enable collecting, summarizing, and presenting business information from different resources to decision makers. When working with BI&A dashboards, interruptions and resulting task resumption failures have negative consequences on decision-making processes. This research in progress paper addresses this problem and provides design knowledge for attention-aware BI&A dashboards that support users during task resumption. We follow a Design Science Research (DSR) approach and derive theory-grounded design principles for task resumption support on BI&A dashboards. Moreover, to evaluate the suggested principles, an instantiation is realized. In our instantiation, real-time tracking of eye-movement data is used to capture visual attention of the users and provide visual feedback after task resumption. We introduce testable hypotheses and present preliminary results of a pre-test lab experiment.

Keywords: Eye-Tracking, Interruptions, Attention-aware System, Business Intelligence & Analytics, Dashboards

1 Introduction

In today's business world, office workers are required to work on several tasks and devices simultaneously. Thus, workdays are accompanied by frequent interruptions or switches between tasks (Czerwinski et al. 2004). Studies show that office workers are interrupted on average every five minutes from their primary task during a regular workday (Jackson et al. 2001) concurrently, people's attention span decreased in the last years (Microsoft Canada 2015). Being confronted with such interruptions while conducting attention-demanding tasks can prompt task-irrelevant thoughts or mind wandering, increasing the cognitive load, provoke mistakes and therefore damage the task performance (Stothart et al. 2015; Bailey & Konstan 2006; Bailey et al. 2000). Moreover, an increasing number of interruptions affects how people distribute their attentional cognitive resources (Franke et al. 2002) as attention is known as a limited resource (Chun et al. 2011). Such multitasking situations with several attentional shifts may lead to task resumption failures. These failures refer to the improper resuming of a task after an interruption (Roda 2011). Existing research shows that be-

tween 23% and 41% of the interrupted tasks are not resumed right away (O'Conaill & Frohlich 1995; Mark et al. 2005) and such tasks require a higher task completion time (Bailey & Konstan 2006).
Making effective decisions is an important task for office workers. Business Intelligence & Analytics (BI&A) systems are a well-known class of information systems to help business users to make better decisions (Watson 2009). The interest in BI&A systems has increased in recent years because of the opportunities associated with data and analysis (Chen et al. 2012). One important concept in BI&A systems are dashboards that refer to a graphical user interface (UI) that collect, summarize, and present business information to the decision makers before making the decision (Yigitbasioglu & Velcu 2012). A dashboard is a communication medium that presents information consolidated on a single screen to achieve specific objectives (Few 2006). Different types of dashboards with different designs exists and are intensively used in today's working environments (Anon 2017).

Meanwhile, the increasing number of interruptions in these environments while decision makers are utilizing BI&A systems to make proper decisions affect their primary task performance (Gupta et al. 2013; Ou & Davison 2011). As an example, operational dashboards are used to monitor the process execution in manufacturing in a real-time while interruptions can have negative affect on monitoring performance. Attention-aware systems are "systems capable of supporting human attentional processes" (Roda & Thomas 2006, p.577) and they are known as a support to improve the individual performance in resuming an interrupted task (Jo et al. 2015; Kern et al. 2010; Mariakakis et al. 2015). Human-Computer Interaction (HCI) design is becoming more important in BI&A (Chen et al. 2012) and a synergistic collaboration of BI&A and HCI to find efficient solutions for handling the huge amount of collected data is suggested by researchers (Holzinger 2013; Toreini & Morana 2017). Although such systems are tested in different fields to reduce the impact of interruptions on the individual performance (Kern et al. 2010; Mariakakis et al. 2015; Liu et al. 2014), to the best of our knowledge, the design of it is not yet investigated in the BI&A context. Therefore, this research project is trying to answer the following research question:

> *RQ: Which design principles of attention-aware BI&A dashboards increase task-resumption performance and ultimately individual task performance?*

To answer this question, we first review related work on designing attention-aware systems that support task resumption. Second, the research methodology following a Design Science Research (DSR) approach is presented. Third, design principles for task resumption support are derived and described in detail. In order to assess the principles, an instantiation is realized and hypotheses are derived. In a pre-test experiment, the feedback that is used as task resumption support is evaluated and the preliminary results are presented and discussed. The paper concludes with a summary of the research and provides an outlook for future research.

2 Conceptual Foundations and Related Work

Nowadays employees are often distracted by interruptions originating from different sources such as IT-mediated notifications, phone calls, or colleagues. These are referred to as external interruptions whereas internal interruptions occur due to own thoughts (Miyata & Norman 1986). Although some of those interruptions have a positive effect on the performance, some have negative effects or both (Addas & Pinsonneault 2015). Regardless of their impacts, users tend to go back and continue their primary task after the interruption while the studies show that the interrupted tasks are not resumed right away (O'Conaill & Frohlich 1995). In addition to that, studies show that the resumption is primary a memory-based process (Werner et al. 2009) and some other general human cognitive, perceptual and motor processes (Salvucci 2010). Resuming the primary task consists of remembering to restart the interrupted task and restoring the context of the primary task (Bailey & Konstan 2006; Cane et al. 2012). The time required for these two steps is called resumption lag (Altmann & Trafton 2004). The interruption lag is known as the time to switch from the primary to the interrupting task (Altmann & Trafton 2004). Traditionally, mouse and keyboard actions are used to measure the interruption and resumption lag (Adamczyk & Bailey 2004; Altmann & Trafton 2004; Iqbal & Horvitz 2007) or detecting strategies for task resumption (Dragunov et al. 2005). Lately, interruptibility was measured with other resources such as psycho-physiological sensors (Züger & Fritz 2015). Moreover, eye-movement data is known as a resource that provides information about the user's visual perception process (Kowler 2011) and recently got attention to be used for measuring the interruption and resumption lag (Cane et al. 2012).

Although eye-movement data is useful to detect the visual behavior of the user while working with a system, it is also known for designing intelligent user interfaces (IUIs) (Henderson et al. 2013; Hummel et al. 2018). Attention-aware systems are a type of IUI that supports users in their attentional choices by collecting information about their attention and adapt the user interface more precisely to their needs (Roda & Thomas 2006). These are known as a type of systems that support users in different phases of interruptions (Bailey & Konstan 2006). As interruptions can affect the performance of the users while conducting tasks in digital environments, the need for interfaces that aid task resumption was discussed by researchers during last years (McFarlane & Latorella 2002). Most practical examples of attention-aware systems with eye-trackers, which support users during task resumption, are found in the domain of HCI. Information gained from the user's visual attention is used to assist the resumption of an interrupted task. For example, *EyeBookmark* by Jo et al. (2015) used an eye-tracking device to support users in recovering the last reading position. Four different highlighting methods were developed to examine their effect on the resumption lag and the reading performance. A mobile attention-aware system that supports users resuming a reading task on a smartphone is *SwitchBack* (Mariakakis et al. 2015). After an interruption, *SwitchBack* guides the user back to the appropriate region by highlighting the last row of the text that was read before an outside distraction. The average reading speed of all participants was increased by +7.7%.

Regarding working environments, the huge amount of interruptions and multi-tasking behavior of users shows the need for such systems to increase the productivity (Iqbal & Horvitz 2007; Parnin & DeLine 2010). Although supporting users to control interruptions in the working environment is discussed and tested in different studies (Dragunov et al. 2005; Liu et al. 2014), to the best of our knowledge none of those studies used eye-tracking devices to support users. Moreover, none of the discussed studies focused on the interaction between users and visualized data while supporting users with task interruption is known as one of the critical issues in IS community (Addas 2011).

3 Research Method

We follow a design science research approach as suggested by Kuechler & Vaishnavi (2008) in order to derive and evaluate design principles for attention-aware BI&A dashboards that support task resumption. The approach guides through the different steps of the design and development process. In the "awareness of the problem" step, a literature review in the field of attention-aware systems that support task resumption, designing BI&A dashboards and interruptions in working environment is conducted. The results of this literature review uncover the lack of research on designing attention-aware systems that support users after an interruption in the field of BI&A. For the "suggestion phase", we examined prior research on task resumption support to derive meta-requirements and design principles for the specific BI&A dashboard context. Meta-requirements are extracted from existing research and design principles are synthesized. In the third phase, different design prototypes of the visual feedback feature and the BI&A dashboard are developed based on the design principles. After that, an instantiation of the attention-aware BI&A dashboard is developed. For the evaluation phase, a pre-test experiment with seven participants is conducted. The participants are divided into an experimental group and a control group while both groups conduct the same predefined primary and interrupting task. The developed visual feedback feature supports the experimental group whereas this feature does not support the control group. In the end, the individual performance of both groups is evaluated based on the resumption lag and the task completion time.

4 Designing Task Resumption Support in BI&A Dashboards

4.1 Design Suggestions

Eye-movement data is known as a resource for predicting visual attention of the users and can be used to analyze cognitive processes and user's intentions (Kowler 2011). Eye-tracking devices are seen as the leading technology for designing attention-aware systems and extracting user's visual attention (Bulling 2016). Processing visualized information of BI&A dashboard such as scanning is done through visual perception (Wickens et al. 2012). Therefore, the first meta-requirement (MR) for designing an attention-aware dashboard, **MR1**, is the necessity to record user's eye-movement data with an eye-tracking device while processing visualized information. Interruptions have a disruptive effect on the performance (Bailey et al. 2000) and attention-aware systems can support the user in handling them (Bailey & Konstan 2006). Furthermore, eye-movements are effective to measure cognitive load, retrieve the visual attention and infer the intention of the user (Carrasco 2011; Orquin & Mueller Loose 2013). Therefore, **MR2** demands to estimate the user's visual attention based on the tracked eye-movement in real-time.

Interruptions are provoking a shift of attention from the primary task to the interrupting task (Speier et al. 1999). Recognizing attention shifts due to external interruption is essential to store the context of the interrupted task and keep it until the task is resumed (Roda 2011; Altmann & Trafton 2004). Furthermore, to assist the user in resuming the primary task, the resumption of the primary task must be recognized. Recognizing a resumption means that the eye-tracking device detects the user's eye movements upon returning to the UI (Mariakakis et al. 2015). Therefore, **MR3** should enable the recognition of external interruptions and **MR4** refers to the recognition of task resumptions and return to the primary task by tracking eye-movements.

To initiate the resumption of the interrupted task, the user needs to remember to resume the primary task and restore the context (Roda 2011). The user interface should support the user during the recovery process (Franke et al. 2002). A visual feedback assists the user to restore the context by guiding the visual attention (Mariakakis et al. 2015). Visual feedback proved to help the individual performance and reduces the resumption lag (Mariakakis et al. 2015; Jo et al. 2015). Therefore, **MR5** should enable providing visual feedback after the task resumption. Most of the attention-aware systems that support task resumption give a visual feedback by highlighting the last gaze fixation or area of interest (AOI) that the user fixated (Kern et al. 2010; Mariakakis et al. 2015; Jo et al. 2015). The last AOI gives a hint about what was in the visual interest of the user before the interruption. At the resumption, the attention of the user is captured by the highlighting and assisting the user back to the relevant points before facing to the interruption (Mariakakis et al. 2015). The unique characteristic of BI&A dashboards in comparison to other user interfaces is the existence of visualized information specifically in the form of charts. Therefore, **MR6** emphasizes highlighting the charts, as AOIs on the dashboard, that received most attention before the interruption in order to provide visual feedback.

Existing research shows that attention-aware systems assist the user during task resumption by utilizing the eye-movement data to infer the visual attention of the user (Kern et al. 2010; Mariakakis et al. 2015; Jo et al. 2015). This research is focused on external interruptions and detecting attention shifts by tracking eye-movement data in a real-time. Therefore, the eye-tracking device recognizes external interruptions of the primary task, as the user is not looking at the screen. These attention-aware systems assume that the user resumed an interrupted task when the eye-tracking system detected eye-movements. Therefore, we suggest the first design principle **(DP1)** that can be seen at Table 1. Moreover, attention-aware systems use visual feedback to assist the user after an interruption such as highlighting either by color or a spotlight the last element that the user was looking at before the interruption (Kern et al. 2010; Mariakakis et al. 2015; Jo et al. 2015). Kern et al. (2010) state that providing visual feedback after task resumption might also be a potential benefit in standard working environments where interruptions might be longer. Czerwinski et al. (2004) found out that approaches capturing and remembering representations of tasks may be useful to assist users in switching among tasks. Therefore, the second design principle **(DP2)** is synthesized.

	Meta Requirements	Design Principles
Visual Attention	**MR1:** Record user's eye-movement data with an eye-tracking device while processing visualized information	**DP1:** Capture user's visual attention by tracking eye-movements and recognizing task interruptions/resumptions based on them
	MR2: Estimate the user's visual attention based on the tracked eye-movements in real-time	
Interruption	**MR3:** Recognize an interruption of the primary task	
	MR4: Recognize a resumption of the primary task	**DP2:** Provide visual feedback after resumption by highlighting charts on BI&A dashboard that received visual attention before the interruption
Visual feedback	**MR5**: Provide visual feedback after task resumption	
	MR6: Highlight the elements that received most attention before the interruption	

Table 1: Proposed the meta-requirements in three categories and the derived design principles.

4.2 Instantiation

To instantiate the design principles, we developed the attention-aware BI&A dashboard with .NET framework. To record the eye-movement data, we used Tobii 4C eye-tracker with the required licenses for research purposes. It is a low-cost screen-based eye-tracker that is mounted to the monitor. The Tobii SDK provides the required methods for developing gaze-aware UIs and detects if or where the user is looking at the dashboard. As illustrated in Figure 1, the implemented BI&A dashboard is able to record and process the eye movement data by means of eye-tracking devices and therefore is sensitive to visual attention and interruptions. Implementation of this attention-aware BI&A dashboard consists of three subsystems, which are structured along the meta-requirements. The eye-movement subsystem stores all collected eye-movements such as gaze duration and fixation duration of each AOI on a database. The interruption handling subsystem detects interruptions and resumptions of the primary task by tracking the presence of the eyes in front of the monitor while the BI&A dashboard is open. The visual feedback subsystem analyses the last stored eye-movements on the database and issues the visual feedback to the BI&A dashboard based on the analysis.

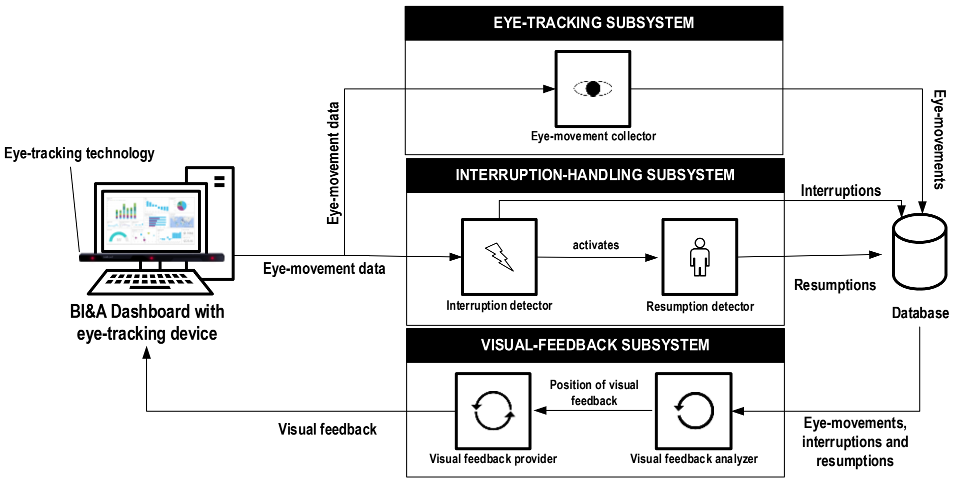
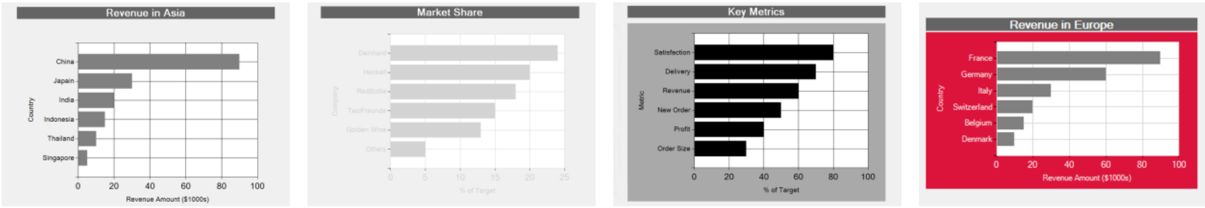


Figure 1: System architecture of the attention-aware BI&A dashboard that supports task resumption

Figure 2 represents the standard chart and three specific types of visual feedback integrated into the BI&A dashboard. The first type of visual feedback is issued to charts that had an interaction time of less than eight seconds. Based on the collected information in the pre-test study with the same dashboard design, eight seconds is the fastest perceptual speed that users need for scanning a chart in this dashboard. Therefore, having interaction time lower than eight seconds means the user did not scan the chart long enough to perceive all presented information and needs to re-scan it after an interruption. The second type is issued to charts that the user interacted for more than eight seconds. This means the user scanned the chart long enough to notice the content of a chart. The third type of visual feedback is shown on the chart that was fixated last by the user before the interruption. We did not consider any time limitation for this type since the purpose is to guide the attention of the user to the last point before interruption. For this type of feedback, the red color is used as a pre-attentive method (Treisman & Gelade 1980) to draw the attention of the users to the last point before the interruption.



Standard Chart (No Visual Feedback) | First Feedback (Interaction Time <8s) | Second Feedback (Interaction Time >8s) | Third Feedback (Last Fixated Chart)

Figure 2: Types of visual feedback

5 Experimental Evaluation

The goal of the evaluation is to show that an attention-aware BI&A dashboard increases the task resumption performance and ultimately the individual task performance in case of an external interruption by providing visual feedback. After an interruption, the visual feedback assists the user to find the last fixation before the interruption (Kern et al. 2010). The interrupted task should be resumed faster with the help of the visual feedback (Jo et al. 2015). The resumption performance is measured by resumption lag which is the time taken to resume the primary task (Altmann & Trafton 2004). Thus, the first hypothesis (H1) is proposed:

> **H1:** *Attention-aware BI&A dashboards with a visual feedback feature increase task resumption performance in case of an interruption.*

The visual feedback feature is designed to guide the visual attention of the user after an interruption. The user is supported in restoring the context of the interrupted task and resumes the task faster (Jo et al. 2015). Resuming the task more quickly leads to an overall better performance of the user (Mariakakis et al. 2015; Parnin & Rugaber 2011). The proxy for a better task performance is defined as a task completion time. This leads to suggesting the second hypothesis (H2):

> **H2:** *Task resumption performance is positively related to individual task performance.*

The attention-aware dashboard assists the user with visual feedback after an interruption. The user is re-directed to where the interruption happened and supported in restoring the context and therefore is expected to improve task performance (Mariakakis et al. 2015; Jo et al. 2015). Such improvement might also be influenced by memory capabilities (Ratwani & Trafton 2008) or further human cognitive, perceptual and motor processes (Salvucci 2010). Therefore, the third hypothesis (H3) is:

> **H3:** *Attention-aware BI&A dashboards with a visual feedback feature increase individual task performance in case of an interruption.*

The research model presented in Figure 3 depicts how the BI&A dashboard with the visual attention feedback feature is proposed to positively influence the resumption lag and task completion time of the users. In addition to the proposed hypotheses, we plan to control for potential moderating effects by the participants' demographics as well as their experience on working with BI&A dashboards.

To evaluate the effect of the visual attention feedback on task resumption, we apply a between-subject design with two groups. Both groups run through the same experiment, except that the control group does not receive visual feedback after task resumption. With this feedback, the experimental group has the support to resume their task and improve their task performance. For the experiment, we developed a BI&A dashboard with a suitable amount of information, the same chart type, and a static interaction with the visualized information. We decided for such a design of the BI&A dashboard to control for potential impacts on sensory memory (Wickens et al. 2012) such as interaction type (Zhicheng Liu & Stasko 2010) or the applied visualized format (Kelton et al. 2010).

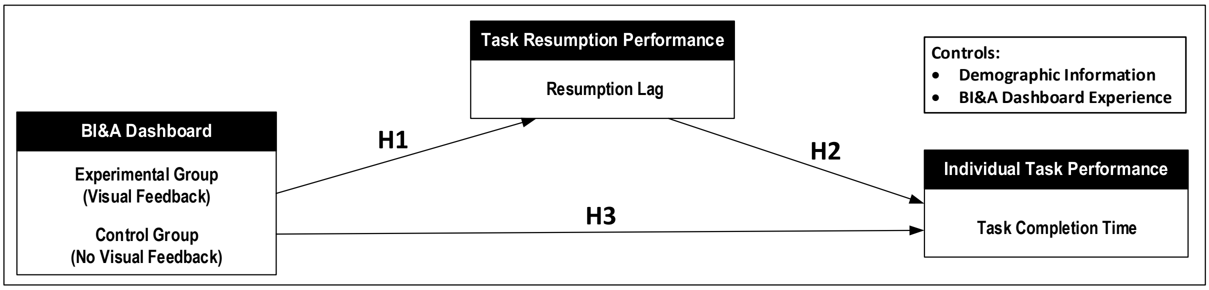


Figure 3: Research model with proposed hypotheses

The experiment's BI&A dashboard includes twelve chartss with the same format (bar chart) to minimize the distractions that affect the users' attentional resources (Lurie & Mason 2007; Patterson et al. 2014). Each chart is considered as an AOI while it includes seven chunks of information as a well-designed visualization promotes chunking (Patterson et al. 2014), and 7±2 chunks of information is known as the magic number for individuals' working memory capacity (Miller 1956). Moreover, we use no color in the design of the dashboard to control for the effect of attracting visual attention via colors in BI&A dashboards (Bera 2016). On the other hand, the color and contrast in the feedback feature are used to support users in the preattentive processing of the feature based on the feature-integration theory of attention (Treisman & Gelade 1980). We are aware that having a BI&A dashboard with the same complexity of the elements does not represent a real-world scenario and more sophisticated BI&A dashboards exist in the real business (Anon 2017). However, this BI&A dashboard is designed explicitly for the experiment to evaluate the effects of the visual attention feedback in a controlled setting.

As a task for conducting the experiment, participants followed an imaginary scenario in which they played the role of sales manager of a company. They were told about a meeting with the CEO of the company at the next day and have to answer questions regarding the sales data. Therefore, they were told to scan the information on the given sales dashboard to make themselves familiar with the visualized data and trends based on the last report. Moreover, as eye-tracking devices were used for designing the visual attention feedback, these devices were calibrated with the standard Tobii 9-point calibration process before conducting the scanning task. When the calibration is done, the participants were asked to start the scanning task, and after a short period, a pop-up window showed up on the dashboard. It instructed the participants to switch to the desk on their left side and conduct an irrelevant task. This step counts as an interruption as the printed version of a news article with two paragraphs and irrelevant content was given to all participants. Changing the task also shifts the working sphere of the dashboard user, therefore, the context of the interrupted task has to be restored at task resumption. In the next step, the participants were asked to go back to their monitor and resume the primary scanning task. The dashboard recognizes the presence of the user and the experimental group received the previously explained visual feedback upon task resumption. The participants finished the scanning task based on their assessment by clicking on a "finish"-button on the BI&A dashboard. In the next step, a recognition test was conducted by showing some charts and investigating if they can recognized them or not. Thereby, it is ensured that the participants undertaken the scanning task properly before clicking on the finish button. As the last step, the participants had to answer a questionnaire includes demographic as well as their experience in working with dashboards.

6 Preliminary Results

This section includes data from a small-scale pre-test study to evaluate the experimental design. For this pre-test, in total seven persons between 21 and 24 years (M=22,57) participated. All participants were male and university students on the bachelor and master level without experience in working with BI&A dashboards (M=3,43). To conduct the pre-test, four participants were randomly assigned to the experimental group while three to the control group. Based on the collected eye-movement data, it can be seen that three of the four members of the experimental group almost immediately looked at the feedback which was highlighting the last AOI before the interruption based on the last fixation position. Moreover, two different strategies of resuming the scanning task can be observed in the next steps. Two participants of the experimental group continued the scanning task by first looking at the charts that were highlighted by a darker grey visual feedback while later, they scanned the charts that had increased transparency. These charts are similar to the background color due to their light grey color. The visually dominant charts were examined first by these participants and then the less visually striking charts. This means that the participants resumed the task by re-scanning the charts they already looked at before the interruption. As discussed by Kern et al. (2010), the visual feedback provides a memory aid to restore the context of the interrupted task faster and they continued with the charts they did not look at before the interruption. On the contrary, two of three participants, who did not receive visual feedback, resumed the scanning task by looking at one of the charts in the center row of the dashboard. On average the experimental group resumed the task faster (M(n=4)=2 seconds, SD=1.41) than the control group (M(n=3)=49 seconds, SD = 48.51). Moreover, the task resumption performance is measured by the resumption lag. The difference in the average resumption lag between both groups is quite large and it supports H1 to some extend. As already shown by Mariakakis et al. (2015), the visual feedback helped to guide back the visual attention to the proper chart after an interruption which is proved by the short resumption lags of the experimental group. On the other hand, the proxy of the individual task performance is the task completion time and the control group completed the task on average a little slower (M(n=3)=5:15 minutes, SD=66.78) than the experimental group (M(n=4)=5:12 minutes, SD= 40.42). Therefore, based on the presented results, H2 is partially supported. All-in-all, the experimental group had a slightly higher individual task performance than the control group, because they resumed the proimary task faster. As a limitation, the defined hypotheses are supported on a non-statistically significant level mostly due to the small sample size.

7 Conclusion

This research in progress paper presents our ongoing DSR project on the design of attention-aware BI&A dashboards that supports task resumption. Thereby, our research is an improvement (Gregor & Hevner 2013) as we address an existing problem (support users to manage their visual attention) by providing the design of a new solution (visual attention feedback for task resumption). Our DSR project will contribute to both research and practice by providing design knowledge for such systems. Although we follow established guidelines, our research includes limitations. First, we only present the experimental design with preliminary results that indicate the potential of the visual attention feedback to improve the task resumption performance and the individual task performance at a non-statistically significant level. However, the proposed theory-grounded design is valuable for researchers and practitioners and promising to support BI&A dashboard users. Second, the underlying theory base is chosen to the best of our knowledge. However, it can be extended using additional theories on the users' human information processing depending on the results of the proposed experiment. As a next step, we will finalize the proposed experimental design and subsequently conduct the experiment. In addition to the research activities outlined in our project, there are further opportunities for future research on this important issue such as designing and evaluating different types of feedback. Moreover, in real-world scenarios, BI&A dashboards include different colors for getting benefit of color coding. Therefore using colored feedback and the effect of it or considering other techniques for highlighting charts should be investigated in real-world scenarios. Furthermore, there is the opportunity to examine if visual attention feedback can be used to support users in recovering from other attentional breakdowns.

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