Understanding Business Dashboard Design
User Impact: Triangulation Approach Using
Eye-tracking, Facial Expression, Galvanic
Skin Response and EEG Sensors

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Abstract

Business dashboard and other visually intensive Business Intelligence applications are cognitive tools requiring users to deploy various levels of cognition and effort in the process of decision making. Due to this impact on cognition and effort, the design of business dashboard has a potential to influence users' responses. Rooted in Cognitive Fit Theory's implications of the role of cognitive effort in the relationship between task-data representation (mis)fit, this emerging research suggests a need to deploy triangulation methodology to measure human responses via biometric sensors in the context of business dashboards. These responses can take the form of attention, emotions, stress and cognitive workload. Research model and questions are presented along with planned methodology and potential practical implications. This research is making a call for more direct and objective measures of user responses in a business dashboard context.

Keywords
Dashboard, Eye-tracking, facial expression, galvanic skin response, EEG

Introduction

One critical part of Business Intelligence systems is their data representation component of visually intensive applications such as dashboards. These applications require from business users to deploy various levels of cognition and effort in the process of decision making (Bacic and Fadlalla 2016). Due to this impact on cognition and effort, the design of business dashboard has a potential to influence users' responses. Literature suggests that these responses can take the form of attention, emotions, stress and cognitive workload.

The main goal of this research is to explore and expand our understanding of how the mismatch between task and data representation impacts dashboard users. More specifically, there are two areas of interest: (1) the influence of task and data representation (mis)fit on user's attention, emotions, stress and cognitive workload and (2) the influence of user's attention, emotions, stress and cognitive workload on decision performance (speed and accuracy) in the context of task-data representation (mis)fit. In the next section 1 provide brief literature review, followed by the research model and research questions. Lastly, the overview of planned research methodology and concluding statements are offered.

Literature Review

Early graphical display literature led to several theoretical approaches attempting to explain decision performance through data representation's impact on users' cognitive effort. The dominant theoretical lens, Cognitive Fit Theory (Vessey, 1991; Vessey & Galletta, 1991), suggests that the matching of presentation format to a task leads to improved decision making by reducing decision maker's cognitive effort, while the absence of the fit tends to degrade decision performance. In the context of frequent and
impactful decision making, the experience of effort (and consequently perceived lack ease of use) has a potential to influence perceived value of dashboards and the level of their usage. In a non-voluntary, work-related environment of business dashboards, previously described experience has a potential to influence user's stress and emotions.

Despite the proliferation of badly designed data displays and dashboards, to the best of my knowledge, no prior research attempted to use biometric technology to explicitly measure impact of such practices on users' attention, emotions, stress and cognitive workload by triangulating across biometric measures of user response. The gap has been recently recognized and presents an opportunity for impactful research stream (Bačić and Fadlalla 2016).

In next few paragraphs I provide brief evidence of biometric research capabilities focused on attention, emotions, stress and cognitive effort in extant disciplines and offer suggestion that those methods could be used in business dashboard context.

**Attention and effort – Eye Tracking**

With exception of Bera (2016), the literature focused on the measurement of attention in a business decision making and dashboard context is scant. However, other disciplines used eye-tracking technology in measuring attention in reading, psycholinguistics, web-site usage, online gaming, writing, and language acquisition. Eye tracking is considered effective in assessing user's attention and effort as it reveals how the user reads and scans the displayed information (Rayner, 1998). Eye-tracking studies have shown that cognitive load impacts eye movement (Djamasbi et al. 2012; Ikehara & Crosby, 2005; Rayner, 1998) and is often assessed through the analysis of fixation count, fixation duration and gaze pattern (Djamasbi et al. 2011). Similarly, related research (Djamasbi et al. 2012) suggests that eye tracking sensors offer insights into cognitive processes; eye fixations and the measure of pupil size are linked to cognitive effort as an individual engaged with effortful or difficult decisions experiences pupil dilation size increases (Beatty 1982). Figure 1 displays piloted data capture of fixation count, duration and gaze pattern in dashboard context.

**Emotional Response – Facial Expressions**

Based on the work by Charles Darwin, a method was designed to help classify human facial movements by their appearance on the face (Hjortsjö, 1969). This method, coined the Facial Action Coding System (FACS), was updated (Ekman et al. 2002) and became a basis for facial expression technology vendors for automating FACS and enabling researchers to identify and understand not only FACS but also combine them to capture emotional valence (positive, negative) and seven basic emotions (joy, disgust, contempt, confusion, frustration, surprise, anger). Some of the relevant research
includes analysis of customer emotions while comparing websites (Quintanar, Trujillo and Watson 2016.), sports (Matsumotoa and Willingham 2006), and computer security (Dong and Sung 2014). Figure 2. displays sample piloted data capture of facial expressions when displaying business information using various types of data display (tabular and graphical)

**Stress – Galvanic Skin Response**

Galvanic skin response (GSR) sensor measures sympathetic nervous system response as an indicator of general arousal. As participant’s effort, engagement, excitement, or anxiety level changes, the sympathetic nervous system reacts by releasing small amounts of moisture in the skin. GSR sensors were used in marketing literature (LaBarbera mand and Tucciarone 1995), understanding responses to music stimuli (Vanderarki and Ely 1992), and attempting to evaluate trust in Human-Machine Interactions (Hu et al. 2016), and emotional responses during use of an enterprise resource planning (ERP) system in a decision-making context (Leger et al. 2014a). Figure 3 displays our research lab’s sample data capture capability: user GSR response during a task while using a business dashboard.

**Cognitive Workload/Effort – EEG**

The effects of (mis)match suggested by Cognitive Fit Theory could be potentially measured by analyzing viewers/decision maker's brain activity. More specifically, electroencephalography (EEG) sensor data can be used in an algorithm to calculate users' cognitive workload. Research suggests that available EEG analysis software can provide a robust and reliable indicator of alertness and cognitive workload (Berka et al. 2004). The use of EEG measures to evaluate cognitive absorption in the context of ERP (Leger et al. 2014b) and other Information System contexts (Müller-Putz et al. 2015) provide an indication of great potential of EEG-based measures to capture business users’ responses.

**Research Model and Questions**

Rooted in Cognitive Fit Theory’s implications of the role of cognitive effort in the relationship between task-data representation (mis)fit, in this pioneering research I plan to address several closely research questions as represented by the models below (Figure 4 and Figure 5).

1. How does (mis)fit between task and data representation in business dashboard:
   a) Impact users’ attention?
   b) Impact users’ emotions?
   c) Impact users’ stress?
   d) Impact user’s cognitive workload?

Figure 3: GSR Data Capture

Figure 4: Model – Fit and User Response
2. Is there a link between:
   a) Attention and decision performance?
   b) Emotions and decision performance?
   c) Stress and decision performance?
   d) Cognitive Workload and decision performance?

**Research Methodology**

Research lab at large Midwestern University will be used to conduct the experiments. The lab is equipped to conduct experiments leveraging leading software platform (iMotions) that integrates subjects’ responses using eye tracking (Tobii x2-30 eye tracker), facial expression (Affectiva), galvanic skin response (Shimmer GSR), EEG (ABM – X10) and survey technology (Qualtrics).

Undergraduate and graduate students enrolled in business courses will participate in the study. Subjects will be surveyed to capture literature supported demographic information. Next, subjects will be asked to provide optimal solution for tasks using either tabular or graphical presentation format. Time will be measured in seconds, while answers will be evaluated for their correctness (accuracy). Subjects’ attention and cognitive effort will be measured using eye tracking technology by capturing previously published eye-tracking measures deployed in extant HCI literature (fixation count, rate, duration, area, pupil size). The valance of the emotions and the levels of seven basic emotions will be captures using web camera and processed using algorithms via facial expressions software. Real-time indicators of stress will be captured by users wearing GSR device. Lastly, cognitive workload will be captured via EEG hardware and software.

Standard experimental practices of IRB approval, consent form, pre-testing and piloting will be completed prior to the actual experiments. Statistical data analyses will be conducted via statistical software (MANOVA for testing results focused on Model in Figure 4 and Regression for testing results focused on Model in Figure 5) to evaluate the significance of the results.

**Potential Implications**

From a practical perspective, our emerging research should be assessed through the context of how practitioners use dashboards and visual data display. With recent improvements in BI vendor capabilities, users have been empowered to author dashboards with relative ease. These technical improvements can have unintended consequence of transferring authoring costs from dashboard designers to high user cognitive and affective costs (attention, emotions, stress and cognitive workload) for the information consumer and decision maker. Consequently, actual understanding of data, dashboard usage and subsequent decision making may be impacted. For that reason, it is particularly important to critically

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Pilot study using eye-tracking found encouraging finding relative to the impact of mis(fit) on users’ attention (fixation count and fixation duration). Insights gained from the pilot will be used to inform the final design of the experiments.
evaluate the usefulness and appropriateness of visual data displays such as dashboards. This research is making a call for more direct and objective measures of user responses in business dashboard context.

REFERENCES


