Applied Ergonomics 46 (2015) 76–83

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Assessment model for perceived visual complexity of automotive instrument cluster

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A R T I C L E I N F O

Article history:
Received 9 July 2013
Accepted 7 July 2014
Available online 15 August 2014

Keywords:
Perceived visual complexity
Quantifiable measurement variables
Assessment model

A B S T R A C T

This research proposes an assessment model for quantifying the perceived visual complexity (PVC) of an in-vehicle instrument cluster. An initial study was conducted to investigate the possibility of evaluating the PVC of an in-vehicle instrument cluster by estimating and analyzing the complexity of its individual components. However, this approach was only partially successful, because it did not take into account the combination of the different components with random levels of complexity to form one visual display. Therefore, a second study was conducted focusing on the effect of combining the different components. The results from the overall research enabled us to suggest a basis for quantifying the PVC of an in-vehicle instrument cluster based both on the PVCs of its components and on the integration effect.

1. Introduction

Advancements in automotive information technology have led to the introduction of new interactive devices for drivers, such as the in-vehicle information system (IVIS; Horrey et al., 2006). An IVIS has the ability to display more information than a conventional instrument cluster, including information on the current driving status, as well as information indirectly related to driving, like maps, entertainment information, and multimedia. To address this opportunity, full LCD displays are replacing conventional analog instrument clusters, which consist of a single display that shows information related to speed, fuel level, navigation, driving assistance, and more (Bellotti et al., 2004; Huang, 2007).

The addition of information in visual displays is closely linked with visual perception and complexity. The principles of visual perception are commonly explained by a top-down interpretation of what humans see based on sensory information from the physical world (Gregory, 1970), and bottom-up information driven by human knowledge (Gibson, 1966). In this research we defined PVC as the degree of detail or intricacy that the user perceives in a visual stimulus by a combination of bottom-up and top-down processing (Gregory, 1970; Gibson, 1966; Lim and Liu, 2009). Therefore, increased complexity in visual perception can negatively affect how drivers process visual information (Noy et al., 2004; Van der Horst, 2004).

Tsimhoni and Green (2001) investigated the influence of visual demands on driving performance in an experiment that measured visual demands and mental workloads when participants read an electronic map displayed in a vehicle both while driving and while parked. Their results highlighted the payoff that exists between visual demands and driving performance. High demand for visual attention to a specific visual display decreases drivers' visual attention to the road (Lee et al., 2007; Liang and Lee, 2010; Xia et al., 2010). This is likely why increasing the amount of information in in-vehicle displays could disturb driving performance and lead to safety concerns. In solving the potential problem of visual distraction arising from an excess of information provided by in-vehicle visual displays, the design and amount of information presented to drivers must be controlled and optimized.

The visual complexity of in-vehicle visual displays has long been a topic of concern. Several studies have focused on the possibility of measuring complexity by objective metrics (Lavie et al., 2011; Huang, 2007; Cummings and Tsonis, 2006). Previous studies applied an image compression technique whereby an image's degree of visual complexity is calculated based on its compressed size (Tuch et al., 2009). Other researchers have proposed an approach whereby an image's visual complexity is calculated based on the length of edges within the image (Lim et al., 2010; Schmieder and

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http://dx.doi.org/10.1016/j.apergo.2014.07.005

Weathersby, 1983). However, these methods for quantifying the complexity of visual stimulus are difficult to apply in the process of designing an IVIS. In-vehicle information has the specific characteristic that different types of information are combined in a single display. Hence, it is important to consider the complexity of the display's individual components. Accordingly, in this research we analyzed the PVC of an in-vehicle instrument cluster based on the PVC of each of its components.

To discuss issues related to the combination of different components to form a single visual stimulus, we revisit Gestalt theory of perception, which states that humans tend to focus on a whole stimulus rather than on its individual parts (Graham, 2008). Gestalt theory introduced the idea that there are differences between the perception of the whole and the perception of its components (Rock and Palmer, 1990). The theory states that different perceptions of the whole are created when different components interact (Rock and Palmer, 1990). This impacts the concept of organization, and provides insights into differences between the perception of individual components and the whole (Rock and Palmer, 1990). In the context of an in-vehicle instrument cluster, individual components can affect a system in different ways when they are combined.

In this study, we investigated individual components' influences on the overall PVC and also evaluate their interrelationships. In this way, this research provides insights into the possibility of evaluating the PVC of an in-vehicle instrument cluster by estimating the complexity of its components. However, as in previous studies, we determined that the combination of different components impacts the perception of complexity (Rock and Palmer, 1990). We conducted a study to propose an assessment model for quantifying the PVC by including the PVC of the estimated components, and then added a factor that considered the effect caused by the combination of the components; these two approaches were combined to form a complete assessment model to quantify the visual complexity perceived by drivers.

2. Research framework

2.1. Research hypotheses

In the present study, we suggest an assessment model to quantify the PVC of an in-vehicle instrument cluster. We first propose the possibility of quantifying the PVC of the cluster by estimating the perceived complexity of its components. That is to say, our first hypothesis was that the estimated PVC of the components that form the in-vehicle instrument cluster can be applied to explain the PVC of the whole instrument cluster.

However, the estimated PVC of each component did not significantly influence the PVC of the whole cluster. Thus, to evaluate the combination of components, we conducted a second study based on Gestalt theory, which states that the whole is different from the sum of its parts, and thus suggests why we were unsuccessful in explaining overall PVC in terms of the components. Our second research hypothesis was that an integration effect exists when different components are combined into the one stimulus of an in-vehicle instrument cluster. Therefore, we added this integration effect as a new factor in the assessment model. Herein the integration effect is defined as the effect of combining different components such as the speedometer, navigation display, and menu into a single display; this definition is based on previous studies of Gestalt theory (Rock and Palmer, 1990; Palmer and Rock, 1994; Stickel et al., 2010; Xiang et al., 2007). Thus, we suggest an assessment model to quantify the PVC of the whole in-vehicle instrument cluster by considering its components and the effect of their integration.

In this study, we conducted a survey and a controlled experiment to evaluate our hypothesis. We developed a statistical model to estimate perceived complexity based on subjective and objective measurements of each of the eight components. We then evaluated the relationship between the estimated PVCs of the components and the subjective perception of the visual complexity of the in-vehicle instrument cluster as a whole. To assess the model to quantify the PVC of the whole display in relation to the PVCs of the components, a multiple linear regression model was used in addition to a factor quantifying the integration effect.

2.2. Measurement variables

Eleven objective, quantifiable measurement variables were selected from previous studies on visual complexity. These measurement variables were applied to objectively quantify factors of the visual stimulus. The objective measurement variables used in this study were stimulus size, icon size, component quantity, number of divisions, color variety, font variety, icon quantity, blank space percentage, text percentage, graphic percentage, and text-to-graphic ratio (Cummings and Tsonis, 2006; Forsythe, 2009; Kemps, 1999; Olivia et al., 2004; Harper et al., 2009; Michailidou, 2008; Stickel et al., 2010; Xing, 2007; Rosenholtz et al., 2007). Table 1 lists the definitions of these variables.

Moreover, for each component we determined which subset of objective quantifiable measurement variables were relevant to the characteristics of each component, as summarized in Table 1.

2.3. Components

Components refer to the types of information that are included in an in-vehicle instrument cluster and presented to the driver. Eight components were identified in the instrument cluster based on the types of information they presented to drivers. The components were classified as providing either conventional information or additional information. Conventional information includes the standard information traditionally provided in a vehicle instrument cluster, such as *speedometer*, *tachometer*, *other gauges*, and the *gear position indicator*. The component labeled *other gauges* refers to other related components that present information in gauge format in the instrument cluster, such as fuel level and engine temperature readings. Finally, the *gear position indicator* refers to the display showing the gear rotation information as the driver selects or changes gears. Additional information refers to information that has been integrated into vehicle instrument clusters more recently, with technological advancements. In this research, we categorized the additional information into four groups: *navigation*, *assistive information*, *entertainment*, and *menu*. *Navigation* refers to information related to vehicle location. *Assistive information* refers to information to help drivers optimize their driving performance. *Entertainment* refers to information related to enjoyment while driving that is unrelated to the main task of driving. Finally, *menu* refers to a graphic user interface that allows drivers to select which information is displayed.

3. Study 1: in-vehicle instrument cluster and PVC of the components

3.1. Method

The aim of this first study was to verify the influence of the estimated PVC of each component upon that of the overall in-vehicle instrument cluster. The study proposes a model to estimate the visual complexity of a component based on subjective responses and objective performance measurements. Subjective