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Optimal parameters of motorcycle instrument panels design for the elderly by using fuzzy logic☆

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ABSTRACT

This study investigates the optimal interface design of motorcycle instrument panels for the elderly. Elements such as needle length, needle width, and minimum needle scale unit that constitute 125 types of motorcycle instrument panel designs were investigated. There were 36 participants selected for this study who used motorcycles as their primary mode of transportation. Their cognitive errors in reading speedometers and fuel meters as well as the required task time and their general satisfaction levels were measured. Finally, the data were translated into fuzzy numbers and the similarity was analyzed to select optimal design parameters. Based on our research, the optimal design for the speedometer needle dimensions were 4.5 cm long, 2 mm wide with a minimum scale unit of 20 scale marks. The optimal design for the fuel meter needle dimensions was determined to be 3.5 cm long, 1.5 mm wide, and with a minimum scale unit of 20 scale marks.

1. Introduction

In recent years, the motorcycle accident rate has gradually increased in European and American countries [1,2]. In addition, the fatalities due to motorcycle accidents were 20–40 times higher than for other vehicles [3,4]. Annual motorcycle accidents and fatalities were several times higher in Asia then comparable accident rates for European and American countries. For instance, every year more than 50% of vehicle injuries and deaths in Taiwan are caused by motorcycles [5]. Operational distractions and other human errors are the primary reasons for the number of motorcycle accidents [6]. Many motorcycle riders are distracted while reading the information on instrument panels that then prevents them from responding quickly to immediate danger [7]. For elderly riders, whose reaction time and perception gradually deteriorate, the reduced ability to properly read an instrument panel can be particularly devastating. These issues directly relate to the rider's awareness of the motorcycle instrumentation panel, particularly the speedometer and fuel meter [8]. Therefore, developing speedometer and fuel meter designs that take into account the elderly's will assist in reducing the rider's distractions and increasing their concentration. Properly designed instrumentation will also increase a rider's resiliency when confronting unexpected situations thereby reducing the probability of accidents.

For the design of end-user interfaces, Shackel [9] generalized three key points: display needles should not be too thin; the needle tips should be thin and pointed, and each scale mark should be wider than the width of the needle. Whitehurst [10]

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discovered that when the display needle of motorcycle instrumentation extends above the scale marks, the rider tends to visualize the indication faster. However, some researchers now suggest that the needle length should be between 1.3 mm and 1.8 mm [11]. Sanders and Peavey [12] discovered the effect of increasing the scale parameters by 1, 5, or 10 units is better than the effect of increasing the scale parameters by 3, 7, or 8 units. However, recent studies discussed that parameters obtained from experiments of particular display panels tend to be more precise [13,14]. In terms of display methods, Heglin [15] showed that needle–action interfaces are better than table–action interfaces. Simmonds et al. [16] found that digital displays are slightly better for reading speed and accuracy than other types of displays. In contrast, the latest study by Liu et al. [8] showed that motorcycle riders prefer needle interfaces to digital interfaces and the design of a panel achieves the optimal cognitive effect when the direction displays are located at the top of the panel on either side. Furthermore, the accuracy and reaction time of users when reading the information from display panels is a significant issue for the cognition process [17]. Additionally, the type of display panel influences the capability of the riders to confront accidents or other dangerous situations. Consequently, improving the design of a display panel will help increase cognitive effects and reduce accidents [18,19].

To summarize, there are various opinions regarding user interface designs and display methods of panel displays in the aforementioned studies. However, there are few studies investigating the influence of the user interface design parameters of motorcycle panel displays on the cognitive effect of elderly riders. Based on currently available research results, this study aims to further investigate which combination of speedometer and fuel meter are the most important for a motorcycle panel to achieve the optimal cognitive effect under different combinations of needle lengths, widths, and scales. Hence, factors such as colors, backgrounds, and panel styles, which were not investigated in other studies, are also not explored in this paper.

The remainder of the study is organized as follows. In Section 2, the methods used to select the study participants as well as the equipment, experimental measurement factors, and design of experiments is presented. In Section 3, the fuzzy logic analysis is presented and divided into two main parts. Section 4 discusses the fuzzy similarity analysis results regarding needle length, needle width, and minimum needle scale unit. The results are then combined into an optimal motorcycle interface configuration for the elderly. The final section provides the conclusions.

2. Methods and equipment

2.1. Selection of study participants

In this study, random sampling was used according to the population ratio of northern, central, southern, and eastern Taiwan to develop a group of people who were suitable for this study. In total, 36 motorcycle riders with valid driver's licenses were initially selected. The 36 participants were selected from 72 qualified people comprised of the following: 24 from northern Taiwan, 18 from central Taiwan, 24 from southern Taiwan, and 6 from eastern Taiwan according to the population ratio. The selected group was comprised of 18 males and 18 females who were all over 50 years of age. The riders participated in all the experiments discussed in this study. All participants were right-handed and used motorcycles as their major transportation mode for their daily life. Additionally, the participants rode an average of more than one hour per day and had been riding motorcycles for at least 20 years.

2.2. Equipment

The computer used in this study was equipped with an Intel Core i-3 CPU, with an ATI Mobility Radeon HD 5470 graphics card. Adobe Photoshop CS5 and Illustrator CS5 were used as the primary design tools to construct simulation interfaces for the purposes of the experiment. Adobe Flash CS5 was applied to the program design (Action Script 3.0) to enable dynamic changes of the simulated panels and record the experimental data of each participant.

2.3. Experimental measurement factors

According to the pilot study by Liu et al. [8], the optimal panel design is a needle–action display using thin needles where the speedometer is on the left side of an instrument panel and the fuel meter is on the right side. The direction displays should be located on both the left and right hand sides. Using the research presented in [8] as the starting point, the following design items were explored in this study, five needle lengths, five different needle widths and five separate scale units. The needle length, width, and scale units were classified as independent variables. Additionally, the rider's cognitive error when reading the speedometer; the rider's cognitive accuracy when reading the fuel meter; the time required by the rider to complete a task, and the user's satisfaction based on a five-point Likert scale were considered as dependent variables. Finally, relevant results from the literature review were introduced as control variables to increase the precision of the data gathering process while reducing the possibility of investigating known results. The specific design attributes evaluated for this study are listed in Table 1.

2.4. Design of experiments

The experiments developed for this study were divided into three parts: (1) the perceptive influence of the length of needles; (2) the perceptive influence of the width of needle; and (3) the perceptive influence of the minimum panel scale unit. In accordance with the concepts of Usability Engineering described by Nielsen [20] for evaluating the perceptive effects of panels, the