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Evaluation of four steering wheels to determine driver hand placement in a static environment

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ABSTRACT

While much research exists on occupant packaging both proprietary and in the literature, more detailed research regarding user preferences for subjective ratings of steering wheel designs is sparse in published literature. This study aimed to explore the driver interactions with production steering wheels in four vehicles by using anthropometric data, driver hand placement, and driver grip design preferences for Generation-Y and Baby Boomers. In this study, participants selected their preferred grip diameter, responded to a series of questions about the steering wheel grip as they sat in four vehicles, and rank ordered their preferred grip design. Thirty-two male participants (16 Baby Boomers between ages 47 and 65 and 16 Generation-Y between ages 18 and 29) participated in the study. Drivers demonstrated different gripping behavior between vehicles and between groups. Recommendations for future work in steering wheel grip design and naturalistic driver hand positioning are discussed.

1. Introduction

Considering the amount of time drivers are behind the wheel, drivers' wants, needs and comfort with the steering wheel are of importance. Because of heavier traffic and congestion on roadways, average commutes are getting increasingly long. The number of commuters tripled between 1960 and 2000 (Federal Highway Administration, 2011). In 2000, 40% of commuters in metro areas traveled over 30 min to work one way, and 14% traveled over 45 min one way (Federal Highway Administration, 2011). One of the primary interactions drivers have with their car during travel time is via the steering wheel. Ideally for safety reasons, drivers should grip the wheel with two hands at all times. However, naturalistic studies have concluded that this is frequently not the case (Jonsson, 2011; Walton and Thomas, 2005). Designing a steering wheel with ideal characteristics to suit various driver populations may elicit safe driving behaviors as well as accommodate drivers with greater comfort during long commutes and short drives.

This study focused on driver impressions of steering wheel grips in order to inform steering wheel design and future research. The automotive industry has a particular interest in the Baby Boomer and Generation-Y age groups because of the current purchasing power and potential future purchasing power of these market segments, respectively (Deloitte, 2008; Healthwise, Inc., 2007). In addition, Baby Boomers face physical challenges not typical of Generation-Y, such as arthritis. Currently, approximately half of Baby Boomers suffer from arthritis, and it is projected that by 2020, there will be 26 million cases (Hootman and Helmick, 2006). Male participants from two different groups (16 Generation-Y, defined as born between 1977 and 1994, and 16 Baby Boomers, defined as born between 1946 and 1964) sat in four different production vehicles and were asked a series of questions about the grip in the vehicle. In addition, anthropometric data were collected.

1.1. History of steering wheel designs

Historically, before the steering wheel, automobiles were equipped with a steering tiller, essentially a joystick that made controlling the vehicle difficult. In 1899 the first car was fitted with a steering wheel to provide increased control and stability (Patrascu, 2010). Though power steering existed in primitive forms as long ago as 1902, it was not widely adopted into vehicle design until 1956 (Patrascu, 2010). While, some automotive companies voluntarily elected to include airbags in their vehicles in the 1970's, it was not until 1998 that air bags became mandatory on all new vehicles slated for sale in the USA, which caused a significant

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change to steering wheel design (Federal Legislation, 2013). The steering wheel served no other purpose than physically maneuvering the vehicle, accommodating the horn, and housing airbags, until the 1990s when technology in vehicles rapidly expanded and began to envelope the center console, while many of the controls began to migrate onto the steering wheel (Patrascu, 2010). Today, airbag regulations, numerous controls, and the needs of designers and engineers dictate the size and shape of the steering wheel (Patrascu, 2010). The overall design of the steering wheel has remained largely stagnate over the last century, and currently very little research is being done regarding drivers' use of and preferences in steering wheel grip design.

1.2. Current steering wheel research

1.2.1. Occupant packaging

Occupant packaging is defined as the layout of space dedicated for the driver and passengers of the vehicle, which include the seat and steering wheel positioning. With the help of past research, the Society of Automotive Engineers (SAE) has generated numerous recommended practices for occupant packaging, such as driver hand control reach, driver selected seat position, and driver's eye locations (SAE International, 2007, 2010, 2011). In 1979 Schneider, Olson, Anderson, and Post contributed to the SAE standards by identifying the variables that most affect a driver's selected position. The primary objective of Schneider et al.'s (1979) research was to measure differences between driver's selected seat position in a non-driving (static) versus driving (dynamic) condition, using 51 male and 57 female participants in six different vehicles. The authors found that the mean difference between static and dynamic adjustments was less than 1.27 cm. In other words, the findings of Schneider et al. (1979) demonstrated that static seat position accommodates the majority of a driver's seating preferences. Because of the Schneider et al. study, studies that use static seating positions have become standard practice.

In addition, Schnieder et al. used stepwise regression analysis to explain the seating variance among participants using 13 measured anthropometric values. Stature overwhelmingly explained between 32% and 62% of the variance for selected fore and aft seat position, and when adjustments were made to accommodate for height of participants, gender differences appeared to be uniform (Schneider et al., 1979).

At present, engineers consider steering wheels within the context of occupant packaging with an emphasis on anthropometric data and ergonomic principles. Moreover, engineers focus on occupant packaging to ensure the safety of drivers and passengers as well as other large aspects of the vehicle, such as wheelbase and roof height. Even though the steering wheel is one of the many aspects considered, simply including it in packaging does not ensure an adequate or desirable design. Many studies have been done to create an effective occupant package methodology (Reed et al., 1999; Vogt et al., 2005). However, simply integrating the steering wheel in the large-scale ergonomics of the vehicle does not sufficiently consider other elements of the steering wheel such as on-wheel controls, materials and grip design.

1.2.2. Naturalistic studies

Few studies have focused on drivers' hand positions on the grip of the steering wheel. An on-road observational study by Walton and Thomas (2005) revealed three different ways drivers placed their hands on the steering wheel: 1) two hands on top of the wheel, 2) one hand on top, or 3) two hands on the bottom of the wheel or off the wheel as if driving with knees. They observed drivers in eight different geographical locations and recorded the number of hands visible on the top part of the steering wheel – either zero, one, or two. The authors found that often times drivers did not grip the steering wheel at the advised "10 and 2" or "9 and 3" in real on-road situations (AAA, 2012; Walton and Thomas, 2005). Across all eight locations, approximately 25% of drivers had two hands on the lower half of the wheel, approximately 25% placed two hands on the top half of the wheel, and approximately 50% used one hand on the top half of the wheel. In the eight on-road locations, there were high, medium and low speed zones, varied traffic volume, accident zones and varied number of lanes. Walton and Thomas (2005) found that the number of hands on the top part of the steering wheel did not change based on accident zones or lane position (left versus center versus right lane) but did change with higher speeds and greater traffic volume, as drivers tended to grip the wheel with more hands.

Jonsson (2011) conducted a study observing natural hand positions of drivers while on a roadway. A researcher photographed drivers at various times and under various lighting conditions on a 70 km/h, straight roadway. From each photograph, gender, seat belt use, mobile phone use, registration number, as well as hand location on the steering wheel were recorded. Hand location was recorded in correspondence with a clock dial: 9, 10, 11, 12, 1, 2, 3. Hands below these locations were recorded as 0. Overall, data from 1,894 photographs were recorded.

Jonsson (2011) found that females and males differed significantly in hand placement position. Of the males, 38% placed the left hand on the bottom of the wheel, 55% placed the left hand between positions 9 and 12, and 20% placed the right hand between positions 3 and 12, while females were 50%, 49% and 29%, respectively. There were no significant differences between men and women for placement of the right hand on the bottom of the wheel (males = 78%, females = 71%), at least one hand on the upper half of the wheel (males = 72%, females = 61%), and both hands on the bottom of the wheel (males = 28%, females = 39%). Both hands on the bottom of the wheel were most common as compared to recorded clock positions (i.e., 9, 10, 1, 2). Jonsson (2011) also found that 18% of all drivers in the study placed both hands on the upper half of the steering wheel, which was comparable to the Walton and Thomas (2005) study that stated 25% of drivers used this hand position.

1.2.3. Simulator studies

Two studies (Imamura et al., 2008, 2009) investigated grip position and style using a driving simulator. The first study (Imamura et al., 2008) surveyed 11 participants about their grip styles and videoed their hands as they drove in a simulator. Data gathered suggested that grip positions and styles varied widely among drivers and that drivers were not necessarily aware of their grip positions and styles. The second study (Imamura et al., 2009) investigated the possibility of using sensors in the steering wheel grip as a way to measure driver behavior. A prototype of a steering wheel with sensors was developed; however, no data were presented on testing the technology with participants.

1.2.4. Grip characteristics

One study by Nishina et al. (2006) focused on user preferences regarding steering wheel grips. Twenty-one males with extensive driving experience sat in a vehicle and used seven sets of adjectives on a continuum to describe the grip of the wheel (soft/firm, elastic/stiff, fitting/non-fitting, rough/smooth, luxurious/cheap, steady/slippery, comfortable/uncomfortable). For example, "firm" was designated as 1, while "soft" was designated as 7, and "non-fitting" was 1, while "fitting" was 7. The data were analyzed utilizing the Kansei method to create a structural equation model to assess correlations and develop two models based on two distinct differences in user ratings. Both models focus on defining comfort by