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DESIGNING A NOVEL STEERING WHEEL FOR GENERATION-Y, BABY BOOMERS, AND ENGINEERS

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ABSTRACT

Historically, the steering wheel has been viewed as a stylistic or utility component of the vehicle; however, as in-vehicle technology increases, the steering wheel may provide a way to integrate technologies into the vehicle. This study built upon a usability study that examined a broad range of steering wheels. In the current study, participants designed their ideal steering wheel for a concept vehicle by using a paper prototyping method. Fifty-five participants (20 young adults 18 to 30 years of age, 20 older adults 47 to 65 years of age, and 15 male automotive engineering graduate students 18 to 30 years of age) were given an outline of a steering wheel and asked to choose their ideal steering wheel functions as well as the types of controls for those functions and stylistic features. Results showed that while there was no single common design, there were trends among the groups. These three groups selected largely similar controls but tended to locate them differently, create unique steering wheel structures and express their wants and needs differently when asked about their designs. Based on trends in participant designs, two prototypes were created for each group and two for a combination of all groups.

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CHAPTER ONE

Introduction

The proposed study sought to identify user preferences for secondary and tertiary controls on the steering wheel. Participants from three different groups (18 to 29 year old engineering students, 18 to 29 year old non-engineering students, and 47 to 65 year old Baby Boomers) created paper prototypes of their ideal steering wheel for a concept car. Participants selected the steering wheel structure (spokes and hubs), desired functions (including radio controls, climate controls, cruise control, suspension adjustments, etc.), type of controls for the selected functions (button, thumbwheel, touch screen, toggle switch, etc.), style elements of the control (back lighting, programmability, etc.), as well as the locations for the functions. Data were summarized to develop two prototype steering wheels for each generation group (i.e., Generation-Y, Baby Boomer, engineers) and suggest design recommendations.

Historically, automotive engineers and designers have viewed the steering wheel primarily as a safety feature, utility and vehicle dynamic component. Automotive engineers frequently focus on the large-scale design issues including the packaging of passengers, while industrial engineers commonly focus on the stylistic and optional details but are primarily influenced by a design path, due to historical precedence or limited supplier options (Vogt, Mergl, & Bubb, 2005). With increasing attention on vehicle interiors, comfort, and safety, the steering wheel may be a current feature of interest for customers as well as a key safety component.

Past research has investigated occupant packaging assessment programs, anthropometric data, reaction time, errors, distraction, and performance differences between older and younger drivers; however, understanding what controls drivers want on steering wheels has not been sufficiently investigated and may serve to improve future steering wheel designs. This paper reviews occupant-packaging literature from the automotive engineering field, human factors research related to automotive design and control selection, as well as briefly summarizes the history and goals of the Deep Orange 1 concept vehicle.   A pilot study, which guided the design of the current study, is describing prior to the current study.

Occupant-Packaging in Automotive Engineering

When designing a vehicle, automotive 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. The steering wheel is one of many aspects considered in occupant packaging. In many of the existing modeling programs such as CATIA, the steering wheel is often represented by a pivot location, telescoping range (if applicable), and range of angles (Parkinson & Reed, 2006). However, simply including the steering wheel in packaging, as in ***Figure 1***, does not ensure an adequate or desirable design. The Society of Automotive Engineers (SAE) provides guidelines regarding occupant packaging and safety requirements such as seating accommodation (SAE J1517 and J4004), driver reach curves (SAE J287), and driver head clearance contour (SAE J1052) (Macey & Wardle, 2009; Parkinson & Reed, 2006). To incorporate these SAE requirements appropriately, automotive engineers typically use software that utilizes digital human models (DHM) (Parkinson & Reed, 2006). These models can be cost and time efficient tools for vehicle interior design. RAMSIS is one program commonly used by automotive manufacturers, which serves to verify occupant packaging rather than generate packaging configurations (Vogt, Mergl, & Bubb, 2005). The Vogt, Mergl and Bubb study assessed the most effective way to use RAMSIS for occupant packaging. The study concluded that the most ergonomically correct technique is to use a fixed eye point, but this technique is impossible, due to the industry's current design approach. Because seats have limited vertical adjustability and drivers cannot be forced to set their eyes at a specific location, this approach cannot be implemented for current vehicle designs. Rather than having drivers' eyes at a fixed location, the automobile industry typically uses a fixed hip point, though heel and hand points are recognized as viable options as well.

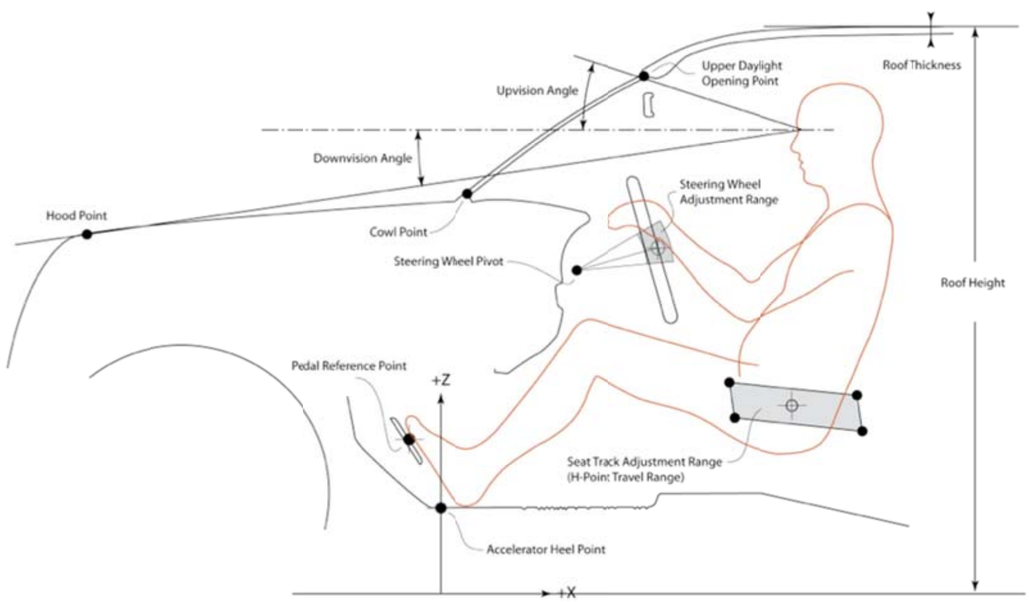


Figure 1. Typical dimensions considered for the driver in occupant packaging. Figure from Parkinson and Reed (2006).

Typically, these packaging and assessment programs are based on anthropometric data provided in the program. Engineers must select population characteristics such as age, gender, and nationality. Using the criteria specified, the engineers use the “mannequins” provided in the program fitting the above characteristics (Vogt, Mergl, & Bubb, 2005). Another common method for creating interior dimensions and designs is selecting percentiles of population (Vogt, Mergl, & Bubb, 2005). For example, engineers may select a 5th percentile female and a 95th percentile male. If the mannequins are selected appropriately and wide ranges of physical characteristics are tested, these procedures can lead to appropriate assessments of the cabin space, seat adjustability, visibility, etc. Unfortunately, much of the existing anthropometric data were collected in the 1950’s and therefore are likely not as no longer applicable to current populations given rapid changes in stature worldwide. For example, obesity worldwide has more than doubled since 1980 (World Health Organization, 2011). This trend may have a significant effect on occupant packaging and other ergonomic issues, such as reach envelopes. Reach envelopes may be affected by factors like age and body mass index (BMI), as well as height and arm length. Although cars are marketed to target audiences, automobile manufacturers realize customers vary from the target customer; however, the discrepancies between target customer and actual customer may not be communicated from the marketing department to the design engineers.

Automotive Seat and Package Evaluation and Comparison Tool (ASPECT), a software program developed at University of Michigan Transportation Research Institute (UMTRI), sought to solve the issues that plague current modeling programs, which include accuracy, population configurability, ease of use, and continuity. ASPECT focuses on user-friendly interface, accounts for real-world driver positioning, and meets SAE guidelines (Reed, Roe, Manary, Flannagan, & Schneider, 1999). Several follow up studies at UMTRI have verified this as a viable packaging program and method (Reed, Roe, Manary, Flannagan, & Schneider, 1999).

Though occupant packaging is a crucial component of vehicle design and addresses key safety concerns (such as visibility over the hood, visibility of gauges, seat adjustment, ability to reach the pedals and general fit of passengers in the front and back seat), it is often addressed late in the design cycle (Parkinson & Reed, 2006). Broad ideas regarding vehicle occupants are frequently decided on early in the design process. In automotive design, the first several steps commonly involve creating ideation about the proposed vehicle, based on marketing data. Afterwards, driver and passenger ergonomics are taken into account during the packaging phase of design and are not considered again until late in the production design, typically near the end of the vehicle's development (Macey & Wardle, 2009). For the current packaging approach to work effectively, there should be minimal constraints in place, but frequently there are many constraints once the occupant packaging is addressed (Parkinson & Reed, 2006). A consequence of designing interiors late in the design process is that when critical issues are encountered, it is oftentimes too late to make the appropriate adjustments without making large structural changes to the vehicle. In addition to limitations from the design timeline, "many procedures in the development process of passenger vehicles are still based on the specific experience of the manufacturer and historical guidelines. These often are arbitrary and subjective, thus the need for more objective, theoretically justified and consistent models" (Vogt, Mergl, & Bubb, 2005) arises. Occupant packaging is the focus of automotive engineers but is not sufficient to ensure that the steering wheel meets all safety aspects, such as reducing distraction and error or satisfying user wants. Both the automotive industry and drivers will likely benefit from additional research efforts on details of the steering wheel rather than solely a large scale packaging effort.

Human Factors Topics in Vehicle Design

Occupant packaging addresses some of the important safety issues of fitting the driver and passengers in the vehicle, while human factors has researched other significant aspects of vehicle interiors and technology, such as driving performance (i.e., speed and lane maintenance), distraction while driving (i.e., technology use while driving) and factors of aging. Because the steering wheel is the driver's primary interaction with the vehicle, the driver's interaction with the steering wheel should be considered including the grip, buttons and other technologies.

Workload. Driving is an inherently complex, high cognitive load task (Tonnis, Broy, & Klinker, 2006). While the act of driving is the primary task, driving is often accompanied by secondary (i.e., blinkers, lights, cruise control, etc.) and tertiary (i.e., radio, climate control, etc.) tasks. Secondary tasks are typically located around the steering wheel and instrument cluster, while tertiary tasks are often located in the center stack, but this classification is an oversimplification since many tasks cannot be categorized this way (Tonnis, Broy, & Klinker, 2006). When numerous tasks are combined (i.e., driving, adjusting the radio, and navigating in unfamiliar places), drivers often experience information overload that is further complicated by contradicting information that must be reconciled and integrated from multiple sources (Tonnis, Broy, & Klinker, 2006). Integrating traffic information from a radio while navigating from directions, safely maintaining lane, avoiding other vehicles, and obeying traffic laws can create complicated and possibly conflicting information that must be integrated into safe driving actions. Integrating this information can cause high levels of cognitive load, which can lead to lower performance in one or more tasks.

Technology in vehicles is expanding at an exponential pace. However, too many individual controls can create cluttered and confusing interfaces for users, so “since the late 90’ies, it has become necessary to decouple the number of functions from the number of direct interaction devices. Some approaches, such as the BMW iDrive have reduced many of the input and output devices down to a single multifunctional controller and a hierarchical menu structure” (Tonnis, Broy, & Klinker, 2006, p. 127). Reducing the number of input and output devices, like BMW’s iDrive or touch screens, can be an effective way to control technologies in the vehicle by reducing clutter and allowing users to create a solid mental model. However, this approach should be applied appropriately, taking into consideration the amount of technology in the vehicle and the capabilities of the user. If poorly executed, users can get lost in menus and be forced to go through several clicks for simple functions.

Steering wheel grip. Few studies have focused on the grip of the steering wheel. One study by Nishina, Nagata, and Ishii (2006) used the Kansei method to create a structural equation model of adjectives that best describe steering wheel grips. Kansei attempts to describe first impressions of an object with specific adjectives and descriptors. Twenty-one males with extensive driving experience sat in a vehicle and were asked to describe the grip of the wheel by using eight sets of words on a continuum. For example, *firm* was designated as 1 while *soft* was designated as 7, and *non-fitting* was 1 while *fitting* was 7. These terms were statistically analyzed for correlations and developed into two models (based on two distinct differences between user ratings) that engineers can use to design steering wheels that meet the expectations of drivers. The full models can be seen in ***Figure 2***.

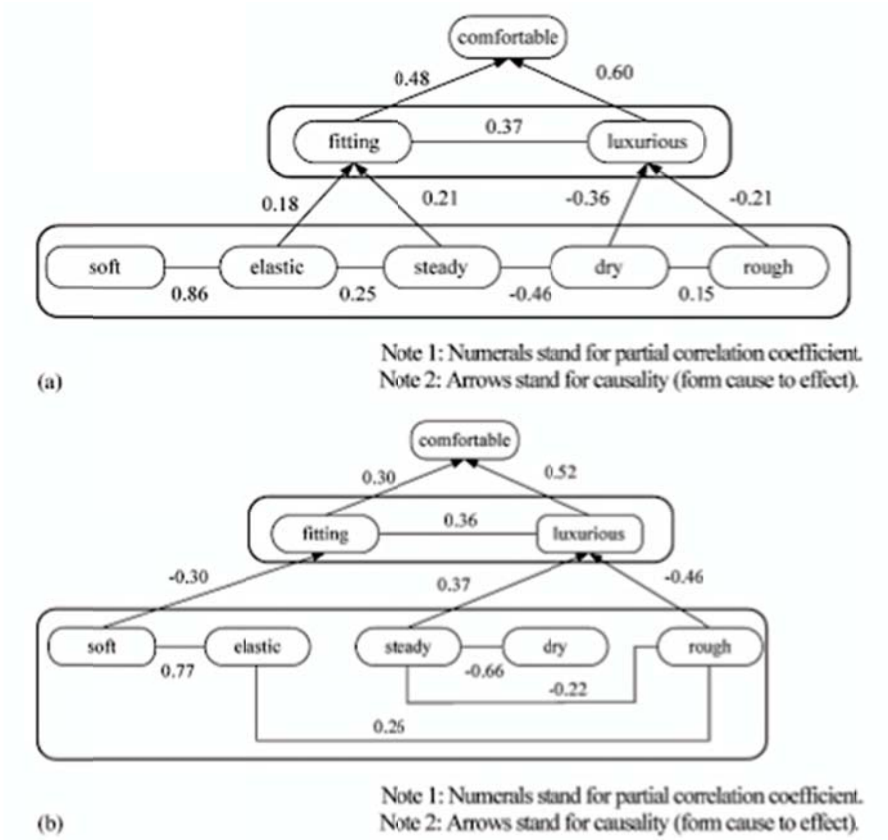


Figure 2. Models developed by Nishina, Nagata, and Ishii (2006): (a) group 1 based on the terms "soft-firm"; (b) group 2 based on the terms "elastic-stiff."

An observational study examining grip by Walton and Thomas (2005) shows that many times drivers do not grip the steering wheel at the advised "10 and 2" or "9 and 3" position in real, on-road situations. Walton and Thomas observed drivers in eight different locations on the road and recorded the number of hands visible on top of the steering wheel: zero, one, or two. In the eight on- road locations, there were high, medium and low speed zones, varying traffic volume, accident zones and varying number of lanes. They found that the number of hands on top of the steering wheel did not change based on accident zones or lane position (left versus center versus right lane) but did change with speed and traffic volume. With higher the speeds and greater the traffic volume, drivers placed more hands on the steering wheel (Walton & Thomas, 2005).

Iconography and Typography. Many studies have examined various automotive design issues involving iconography and typography, including concerns like aging users, contrast, font size, icon complexity, etc. (Legge, Rubin, & Luebker, 1987; Nielson, 1995; Sibley, 2008). In other industries such as the military, standards have been created to ensure ease of use across technologies, geographies, and contractors (U.S. Department of Defense, 2011). However, text and icons used specifically in automotive design are largely unregulated. Some standards do exist for emergency and alert lights such as engine oil, check engine, headlamp beam control, turn signals, etc. (Society of Automotive Engineers, 1996). For text and icons used for labeling controls or interfaces, manufacturers may select their own fonts and icons. Recently, Ford Motor Company announced they were changing the font size in their vehicles to better accommodate aging drivers (Ford Motor Company, 2011), suggesting that design details such as font size can have significant effects on drivers.

User-control Interaction. In the past, many human factors studies have been conducted on user-control interaction. Many of the studies involving button size, shape, and feel were conducted during the 1940s and 1950s and have since been validated in various studies (Kroemer, Kroemer, & Kroemer-Elbert, 1994). One of the most cited studies on user-control interaction is Fitts' Information Processing study. Fitts determined that the time to complete an open loop movement (like pressing a button) could be calculated using the diameter of the target and the distance to the target (Fitts, 1954). A follow- up study conducted by Stoelen and Akin (2010) looked at rotational tasks in comparison to Fitts' law. Their study found that translational (i.e., touching between two places), rotational (i.e., turning a knob), and combination translational and rotational (i.e., a posting task) tasks took the same amount of time to complete. The studies by Fitts (1954), as well as many other studies from the same time period, resulted in the creation of Military Standards for Human Engineering (MIL-STD 1472F) (Department of Defense, 1999). MIL-STD 1472F specifies the appropriate size of controls and force required to manipulate various types of controls. To use these standards properly, a designer must first choose the type of control (i.e., button, knob, lever, etc.) and then specify how the control is manipulated (i.e., a palm, thumb, finger, etc.). After choosing the control type and manipulation technique, various charts can be used to determine the appropriate size and force required. Other factors, such as gloved versus bare hands, are also taken into consideration in these standards (Department of Defense, 1999; Kroemer, Kroemer, & Kroemer-Elbert, 1994). This has become a widely referenced source when designing for buttons in most situations and environments. MIL-STD 1472F does specify a diameter for steering wheels, based on whether or not the vehicle has power steering, but since the 1950s when these standards were developed, there have been significant advancements to power steering technology. As with many of the specified guidelines, a guideline's appropriateness for current technologies should be considered.

With increased attention on distracted driving, NHTSA published guidelines for in-vehicle technology design in 2012 (National Highway & Traffic Safety Administration, 2012). Based on research, NHTSA suggests that in-vehicle technologies not require more than two seconds for a glance and not more than 12 seconds of total glance time to complete a task. While the research and guidelines are specifically directed at light passenger vehicles (i.e., cars and small trucks) and may not be ideal for larger vehicles or motorcycles, NHTSA also suggests these guidelines may be an appropriate rule of thumb until further research can be done conducted.

New controls are being developed that may help alleviate some of the control complexity in vehicles. One issue with the increasing number of controls is the use of stalks (located behind the steering wheel) for complex tasks such as setting and adjusting the cruise control. Stalks require that drivers, at least partially, release the steering wheel to manipulate them (Farina, Rodriguez-Andina, Doval, del Rio, Pelaez, & Blanco, 2004). Other design options may be viable solutions for reducing control complexity on steering wheels, such as the button or thumbwheel based, modal system developed by Farina et al. (2004) to manipulate radio and cruise control. Gonzalez, et al. (2007) proposed a miniature touch screen system on the grip of the steering wheel for navigational input. The small touch screen would allow drivers to enter letters on the screen with their thumbs in order to enter navigation destinations (Gonzales, Wobbrock, Chau, Faulring, & Myers, 2007). Thus, it seems likely that research on control principles and design may be applied to steering wheel design.

Controls in automotive application. Recent studies specifically regarding the incorporation of buttons on steering wheels have been focused on (a) user-control interaction modeling programs, (b) performance criteria such as reaction time, (c) locations of controls, (d) specific populations, or (e) buttons in relationship to displays. Santos is an interior assessment software tool that focuses on interactions with the driver and controls, thus incorporating human and control kinematics and dynamics (Yang et al., 2007). In addition, Santos includes posture prediction, biomechanical assessments, dynamic motion prediction, hand biomechanics and zone differentiation tools (Yang et al., 2007). Programs like this could be used in automotive design for assessing the interaction between the driver and various controls like steering wheels, steering wheel components, pedals, gearshift and the center stack.

Murata and Moriwaka (2005) investigated reaction time, error and subjective workload between steering wheel button configurations (vertical and cross-type) and number of controls (3, 5 or 7). Participants performed single and dual tasks in a driving simulator. Participants conducted a primary task (a tracking task) alone and / or with a secondary task (pressing a number on a control that corresponded with a display on the gauge cluster). The authors found that in the dual task scenario, button arrangement did not affect error rate but did affect reaction time. There were significant main effects of both configuration and number of switches on single ($p < 0.01$ and $p < 0.01$, respectively) and dual tasks ($p < 0.01$ and $p < 0.01$, respectively) as well as an interaction of configuration and number. The interaction of arrangement by number was also significant in the single and task conditions (both $p < 0.01$). Subjective ratings of workload and ease of operation revealed that cross-type arrangements with few controls were most advantageous. Because of the interactions of arrangement and number of controls, the number of switches used was affected less in the vertical arrangement than in the cross-type, but with fewer switches a cross-type interaction is preferred (Murata & Moriwaka, 2005).

Some studies have considered special populations like older adults in studies that measure driving performance and distraction (Dukic, Hanson, & Falkmer, 2006; Murata

& Moriwaka, 2007). Murata and Moriwaka (2007) investigated older (65 to 76 years of age) and younger (21 to 24 years of age) male adults' errors while performing primary (a tracking task) and secondary (operating the controls and displays) tasks with varying display and respective control locations. The display was presented on the right side (on the center stack) or in front (in the instrument cluster), with the respective controls located on the center stack or on the steering wheel. Results revealed that there were no significant age effects for the single task conditions (tracking task only); however, in dual task conditions, older adults performed more poorly than younger adults at the tracking task overall, as well as overall lower performance on the secondary tasks as compared to young adults' performance on the secondary tasks. In addition, older adults had slower overall reaction times than younger adults. The authors found that display and control location compatibility were significant to reaction times. Overall for both older and younger adults, displays and controls located in front of the driver produced the lowest completion times for both single and dual tasks. Displays on the center stack had lower reaction times when coupled with controls also on the center stack. Similarly, displays in front produced lower reaction times when coupled with steering wheel controls (Murata & Moriwaka, 2007). A study on safety perceptions and steering wheel deviation as a function of age and push button location found that age and location had significant effects on visual time off road and steering wheel deviations. The farther the button was horizontally from the line of sight, the more visual time off road, the larger the steering wheel deviation, and the poorer the safety perception (Dukic, Hanson, & Falkmer, 2006).

The study by Makiguchi, Tokunaga, and Kanamori (2003) investigated the memorizability of various configurations of controls and the various symbologies for the controls. For control layout, the number of controls and number of groups of controls did not affect participants between ages 20 and 69 but did affect the over 70 year old group. Two groups of three objects each were easiest for the over 70 age group to memorize. Unfamiliar symbologies increased recall errors for all age groups. Single letter symbols were easiest for participants to memorize in all grouping configurations, see ***Figure 3***. The authors noted that searching without reliance on visual resources should be investigated further as this may not draw as heavily on already limited cognitive capabilities.

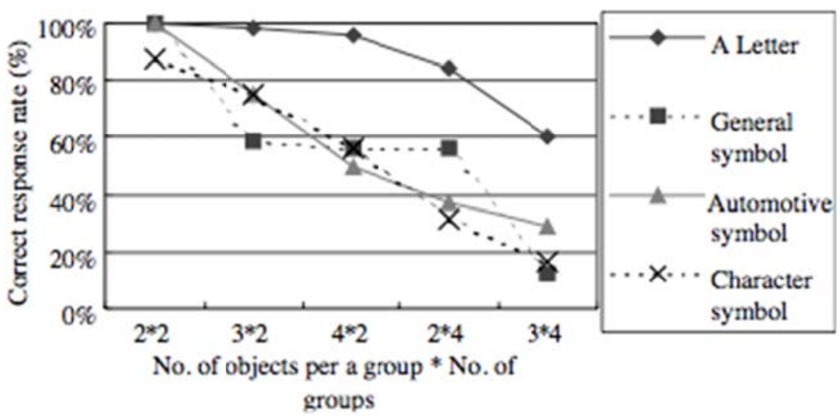


Figure 3. Memorizability of various symbol types **(Makiguchi, Tokunaga, & Kanamori, 2003)**.

Based on the study findings in the literature, display and control locations should be taken into account during cockpit design for both accuracy and safety purposes. Understanding what is of most importance and use is critical in determining where controls should be located. Creating controls that facilitate easy, fast and correct usage may help drivers focus on their primary driving task and reduce their mental workloads on secondary tasks. In a study conducted for Chrysler Group LLC, Green, Kerst, Ottens, Goldstein and Adams (1987) explored driver preferences for secondary controls where participants selected the type and location of the control for a certain function. One hundred and nine participants (male =55) from three age groups (18-29 years of age, 30-54 years of age, and 55-78 years of age) were seated in a vehicle mock up. Then they were asked to choose one of 255 types of controls outfitted with Velcro©, including stalks, push buttons, rocker switches, etc., for 25 functions (horn, high beam flash, climate control, cruise control, dome light, windshield wiper, etc.) and to place it in the desired location. Next, the participants were asked to describe the interaction or manipulation behavior of the control (i.e., blinker located on the stalk and moved up and down for right and left, respectively). Participants were then asked to use their own arrangement of controls they had just created while driving in a driving simulator and performing specific tasks using the controls. Their difficulties with the controls were recorded. Based on their interactions with their own controls, participants were allowed to revise their designs. While data analysis showed that no single design was favored by all participants, some trends in the designs could be attributed to age, gender or both. For example, the rear defrost and rear wiper location varied by sex; the radio location varied by age; the radio, rear defrost and rear washer varied by an age by sex interaction. Younger participants preferred that the radio be located as high as possible on the center stack, while older adults placed the radio lower on the center stack. The age by sex interaction was not fully analyzed because it was difficult to interpret. Male participants wanted rear window defrost and rear wiper on the floor of the vehicle or the right side of the dash near the wheel, whereas female participants chose to place these controls on the lower left of the dash. As a result of the Chrysler study by Green et al. (1987), many of these design preferences can be seen in current vehicle designs. For example, high beams were preferred to be on the left stalk and pushed forward; climate control and radio were preferred in the center console; turn signals were preferred on the left stalk. The authors noted that while asking participants to create designs with current technologies gives in-depth insight to user preferences, understanding why participants made their selections may lead to better predictions about how designs should be approached for many years into the future. Green suggested that due to rapidly changing technology, the study should be replicated in 5 to 10 years, and the reasons why participants made their choices should be re-examined (Green et al., 1987). However, since this 1987 study, there has not been a published follow-up study incorporating newer technology now seen in vehicles.

CU-ICAR and Deep Orange

CU-ICAR is Clemson University's graduate automotive engineering program in Greenville, South Carolina, which seeks to teach and develop automotive engineers to be equipped for working in the automotive industry. The Deep Orange initiative was created to give students a hands-on learning experience in systems integration, an area typically lacking in engineering education (Venhovens & Mau, 2011). A new Deep Orange concept vehicle is developed every year, beginning with market research, going through engineering and development, and ending with a working concept vehicle.

Deep Orange 1 was the first vehicle in the Deep Orange initiative that targets Generation Y, those individuals born in the 1980s. Four aspects of vehicle design have become the focus of Deep Orange 1: technology integration, comfortable seating, best in-class fuel mileage and great styling. The resulting vehicle is a small, electric hatchback that is based off of the BMW 1 series platform. Current efforts focus on the interior of the vehicle. By understanding the wants and needs of the user, designers may better be able to incorporate designs that will create a positive and engaging driving experience. Therefore, based on information obtained from a pilot usability study that investigated how users interact with current steering wheel designs with four production sports car steering wheels, the current, second study will seek to understand the user's wants and needs for a steering wheel for a vehicle such as the Deep Orange 1 vehicle.

CHAPTER TWO

Pilot Study

In order to assess current production steering wheel designs, a two-part pilot study was conducted which consisted of a heuristic evaluation and a usability study. The heuristic evaluation highlighted problems that could occur for various types of users, while the usability study examined user preferences in four production steering wheels.

Heuristic Evaluation

A heuristic evaluation was conducted on six production vehicle steering wheels: 2004 Mazda RX8, 2010 Mazda2, 1991 Mazda Miata, 2006 BMW 535xi, 2003 Toyota Tundra, and 2009 Mazda CX-7. Four personas were chosen to reflect target users of the Deep Orange 1 car and to understand issues with steering wheels that could be encountered by a variety of users. Personas included an average height college male (70 inches), an average height college female (64 inches), a tall and large (75 inches and over 225lbs) male, and an average height (70 inches) lower body-disabled male. The following common issues among all production vehicle steering wheels were found: slippery steering wheel grip, small grip diameter, location causes knees or thighs running into the steering wheel or column, location causes ingress and egress issues for the lower-body disabled, confusing or inconsistent symbols, partially covered gauges for some, and difficult to reach buttons.

Usability Study

The study included the following four vehicles: 1991 Mazda Miata, 2004 Mazda RX-8, 2010 Mazda 2, and 2006 BMW 530xi. See ***Figure 4***. Sixteen male participants, ages 18 to 30 years (mean= 25 years), who possessed a valid driver's license participated in the study.

First, participants answered a series of background questions (including questions about preferred grip diameter based on the diameters of wooden dowels and body height) prior to sitting in each vehicle. Once the participant was seated in the vehicle, each participant answered questions about the grip, which were adapted from Nishina, Nagata, and Ishii (2006), as well as questions about the buttons (see ***Figure 4***) and the steering wheel as a whole. Then, participants were asked to adjust the seat and steering wheel to the position that was most comfortable to them. Participants were asked to move their foot quickly from the gas to the brake and back to the gas. If contact was made with either the steering column, the steering wheel, or other parts of the vehicle, it was recorded. To record naturalistic hand locations, participants were allowed to place their hands where they were most comfortable on the steering wheel, and the data were recorded. For the remainder of the questions, participants placed their hands so that their thumbs rested on the horizontal spokes of the steering wheel, which ensured data could be compared across vehicles. After participants had been asked questions about each car, they were asked to rank preferences of the buttons and grip of each of the four steering wheels, answer open-ended questions and respond to situational questions.

Figure 4. Steering wheel buttons on four production steering wheels. From the top to bottom: 1991 Mazda Miata, 2004 Mazda RX-8, 2010 Mazda 2, and 2006 BMW 530xi.

Table 1 provides an overview of the findings from the usability study. Button and grip questions that focused on stylistic aspects (i.e., luxurious versus cheap, and comfortable versus uncomfortable) showed significant differences between cars, whereas questions that focused on functionality (i.e., easy to reach versus difficult to reach, or distinct versus no tactile feedback) or usability did not report significant differences between cars.

Table 1. Overview of significant and non-significant results from pilot study.

<table>
<tr><th colspan="2">Significant</th><th colspan="2">Not Significant</th></tr>
<tr><td>Button</td><td>Volume size</td><td rowspan="7">Button</td><td>Volume reach easy / Difficult</td></tr>
<tr><td rowspan="3">Buttons layout</td><td>Clean / Untidy</td><td>Volume function obvious / Unclear</td></tr>
<tr><td>Luxurious / Cheap</td><td>Volume tactile feedback</td></tr>
<tr><td>Trendy / Out of style</td><td>Radio size</td></tr>
<tr><td rowspan="6">Grip</td><td>Rough / Smooth</td><td>Radio reach easy / Difficult</td></tr>
<tr><td>Luxurious / Cheap</td><td>Radio function obvious / Unclear</td></tr>
<tr><td>Comfortable / Uncomfortable</td><td>Radio tactile feedback</td></tr>
<tr><td>Comfort on 5 hr. highway road trip</td><td rowspan="4">Grip</td><td>Soft / Firm</td></tr>
<tr><td>Comfort on 1 hr. city traffic</td><td>Pliable / Stiff</td></tr>
<tr><td>Overall comfort</td><td>Fitting / Non-fitting</td></tr>
<tr><td rowspan="2">Other</td><td>Steering style in varying situations</td><td>Steady / Slippery</td></tr>
<tr><td>Percentage who cannot see instrument cluster</td><td></td><td></td></tr>
</table>

Naturalistic grip positions show that participants grip the steering wheel differently in each car (see ***Figure 5***), which can been seen on the neutral, geometric steering wheel and when grip positions are shown on an image of the vehicle's steering wheel; grip position seems to be influenced by the cross bars of the vehicle and perhaps other characteristics of the steering wheel or vehicle design (i.e., arm rests). At the end of the study, participants were asked what functions they would like to include on their ideal steering wheel (see ***Figure 6***). Many of the features listed by participants are included currently on some vehicles (i.e., radio and volume controls); however, several participants listed features not currently located on the steering wheel. For example, two participants wanted sunroof controls and eight wanted climate controls. Participants identified phone controls and cruise control as features they would like to have on a steering wheel, and while some vehicles place these controls on the wheel, many do not. Finally, participants were asked what type of control they would like for volume adjustment (***Figure 7***) and cruise control increase and decrease speed functions (***Figure 8***).

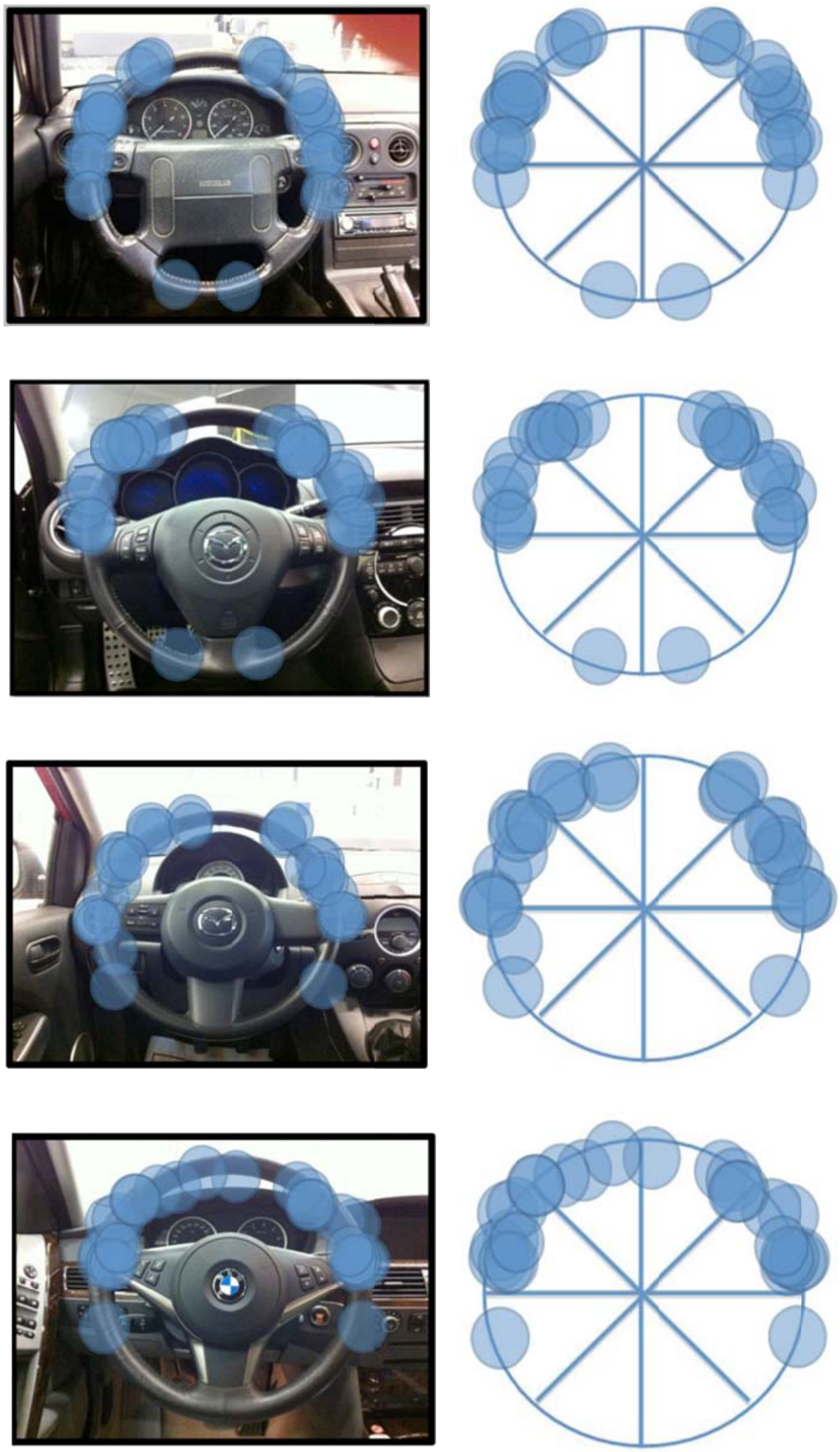


Figure 5. Natural grip positions of drivers in a vehicle. From the top: 1991 Mazda Miata, 2004 Mazda RX-8, 2010 Mazda 2, and 2006 BMW 530xi.

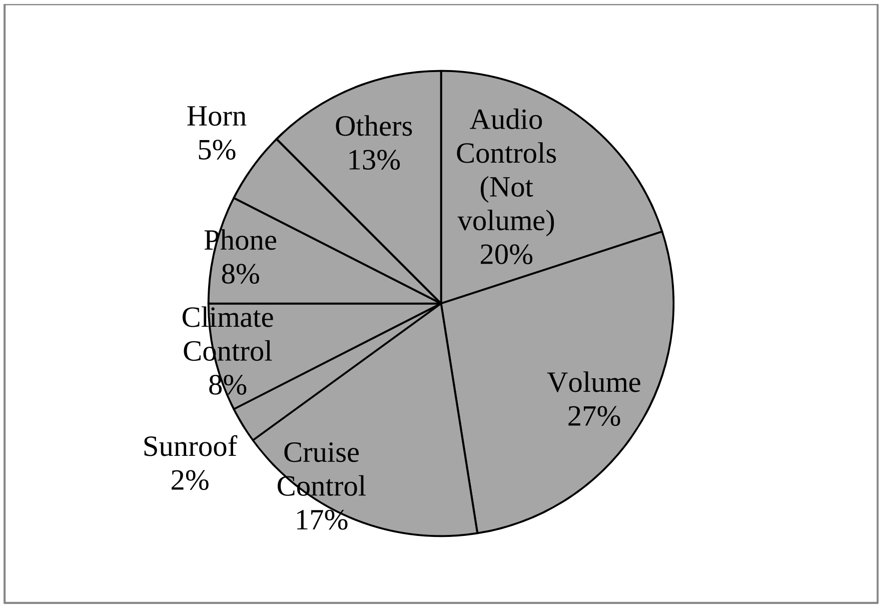


Figure 6. Participant responses to the question, “What are the functions you would want on your ideal steering wheel?”

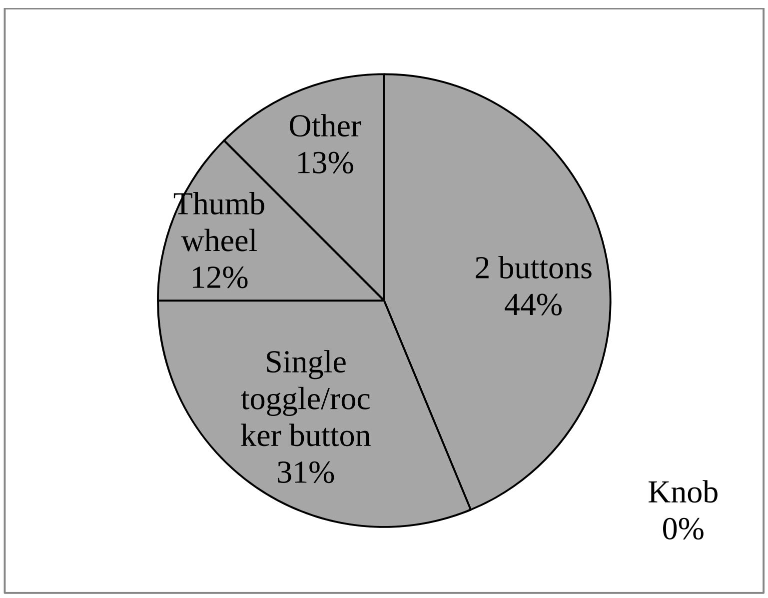


Figure 7. Participant responses to the question, “What type of control would you prefer for volume adjustment?”

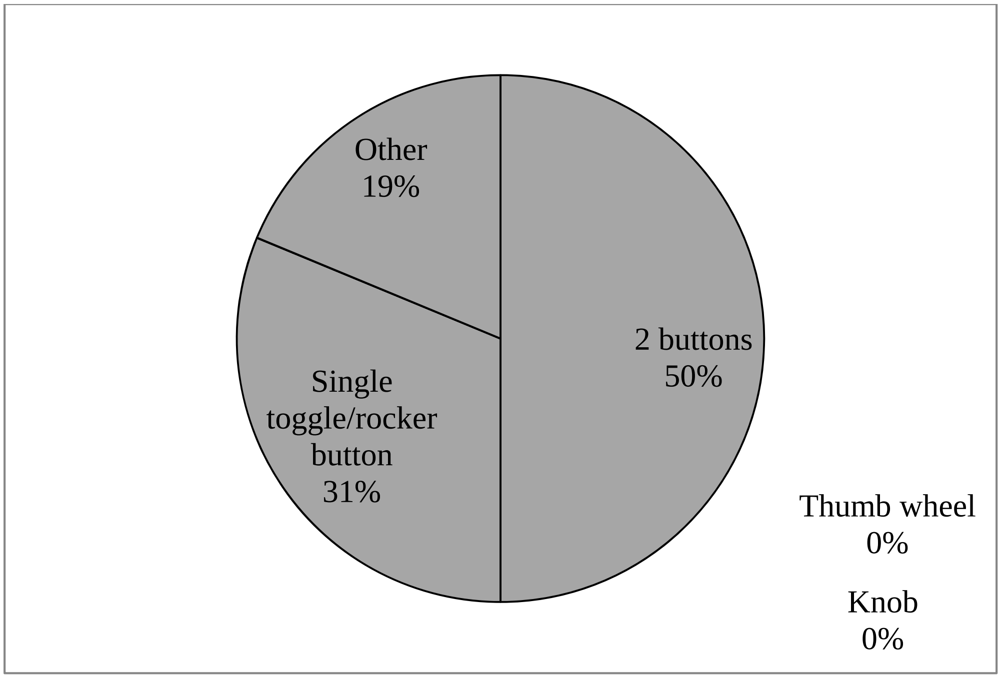


Figure 8. Participant response to the question**, "**What type of control would you prefer for cruise control accelerate and slow?"

The pilot study suggests that there are significant issues with current steering wheel designs, such as slippery grip and poorly located steering wheel that interferes with driver movements. The pilot study also found that participants often did not distinguish large differences between vehicles used in the study. Based on these pilot study findings, the current study sought to understand user steering wheel design preferences without the restriction of current designs, rules, or regulations by giving participants the opportunity to design their own paper prototype of a steering wheel from a template. Participatory design can be a fast and efficient way to generate new designs and to break down barriers between technical specialists and the users (Schuler & Namioka, 1993). By incorporating user feedback and allowing users to create designs that reflect their wants and needs, designers and other technical specialists can gain an understanding of what is most important to the user, insight that is often lost when the design process stays in-house.

CHAPTER THREE

Current Study

This study sought to identify the steering wheel features, preferences and locations for a concept vehicle, such as a Deep Orange vehicle, in three different groups of participants, Generation-Y non-engineering students, Generation-Y engineering students, and Baby Boomers. The participants were provided with a steering wheel outline and a variety of pre-cut shapes in varying sizes. Using these pre-cut shapes, participants built their ideal steering wheel by first selecting the structure and then choosing the spokes and the hub of the wheel. Afterwards, the participants selected and placed their preferred functions. (Note: In this paper, the term "function(s)" refers to an operation to be performed by the system. For example, turning the volume down is a function. A "control" is the physical control used to elicit a function. For example, a knob can be used to turn the volume down. A "button" is a specific type of control. A button may be the control that elicits the decrease volume function). While completing their design, participants answered a series of questions about each function, and after completing their design, they were asked a series of follow-up questions to assess design preferences.

To summarize the data, layers of each design feature were created using Adobe Photoshop. The frequency of functions and their locations was analyzed. It was expected that the younger participants would include significantly more items on their designs and more advanced technologies such as touchscreens.

Method

Participants

Fifty-five participants with a valid driver's license and more than two years driving experience participated in the study. These 55 participants were split into three groups: 15 male, graduate automotive engineering students between the ages of 18 and 30, 20 non-engineering adults (10 of which were male) between the ages of 18 and 30, and a group of 47 to 65 year old Baby Boomers (10 of which were male). All volunteers gave consent and were compensated $10/hour for their time, with a maximum of three hours.

The following basic demographic data were collected from each participant: age, gender, and model year of participant's current vehicle, as well as a brief survey about technology affinity, which used some questions from the 2009 Oxford Internet Survey. In order to identify factors which could influence an individual's design, participants were asked a short series of questions about their technology use, including but not limited to questions about frequency of cell phone use and technology's impact on society and daily life. All technology affinity questions and responses can be seen in Appendix A. After combining the results from questions, technology affinity was rated on a scale that ranged from 6, which represented very positive attitudes towards technology, to 30, which represented very negative attitudes towards technology. Participants' demographics can be seen in Table 2.

Table 2. Participant demographics.

	Age			**Vehicle model year**		**Technology affinity***	
	M	**SD**	**Range**	**M**	**SD**	**M**	**SD**
Baby	57.1	4.8	18 - 29	2001	8.4	12.3	3.8

Boomer							
Generation-Y	21.6	2.7	21 - 28	2001	5.4	10.2	2.3
Engineer	24.0	1.7	47 - 64	2000	7.2	11.8	2.7
*Range: 6 to 30 6= Tech is "good" 30 = Tech is "bad"							

Materials

A laptop computer was used to play a video that provided an overview of CU-ICAR, Deep Orange, and the Deep Orange 1 concept vehicle to participants who were unfamiliar with the Deep Orange initiative. The 4 minute 40 second video which the participants viewed was developed by Clemson University (http://www.youtube.com/watch?v=3sh3ooZNhCc) to explain the goals of the project and the importance of Deep Orange to both the automotive industry and students at CU-ICAR (Clemson University, 2010). All participant materials were arranged similarly in two locations to prevent participants from having to travel long distances. ***Figure 9*** shows an example of one of the data collection sites. To encourage brainstorming, pictures of 12 different steering wheels were displayed on a wall in front of the participant to illustrate unique ideas and examples of steering wheel designs (see Appendix C). Pictures included steering wheels of antique cars, Formula 1 racing cars, concept cars and current production cars.

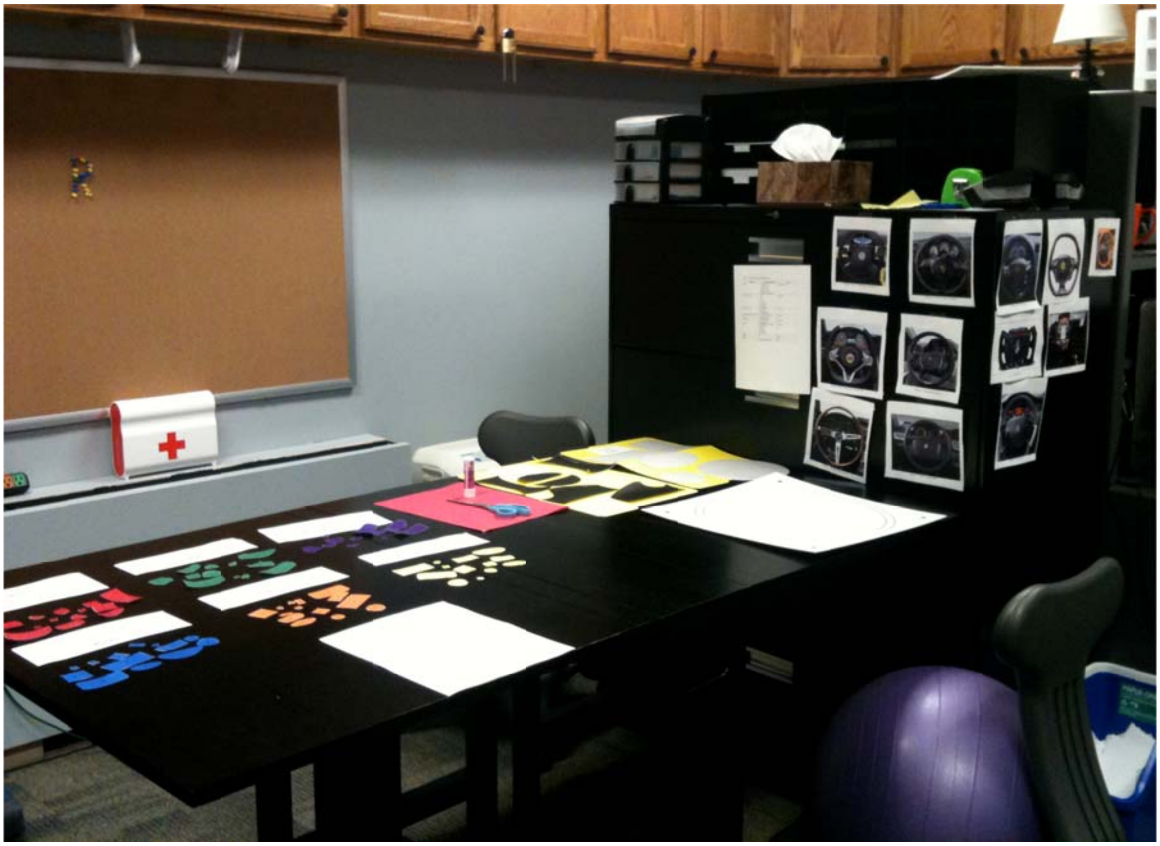


Figure 9. Picture of the lab set up including steering wheel pictures and shape arrangement.

Steering wheel outline and grid. Participants were given one 38 x 38 cm square piece of cardboard with a true-to-size, black steering wheel outline. The outer grip diameter of the wheel was 37 cm while the inner grip diameter of the wheel was 34 cm, replicating the size of the wheel designed for the Deep Orange 1 car as well as the size of the wheel in many small sports cars. In the center of the steering wheel was a 37 cm circle which represented the airbag of the vehicle. For the data analysis process, four dots were printed 2 cm from the edges of the square poster board in the four corners (see ***Figure 10***). The dots were used to align layers of the pictures in Adobe Photoshop to create a composite image of the data.

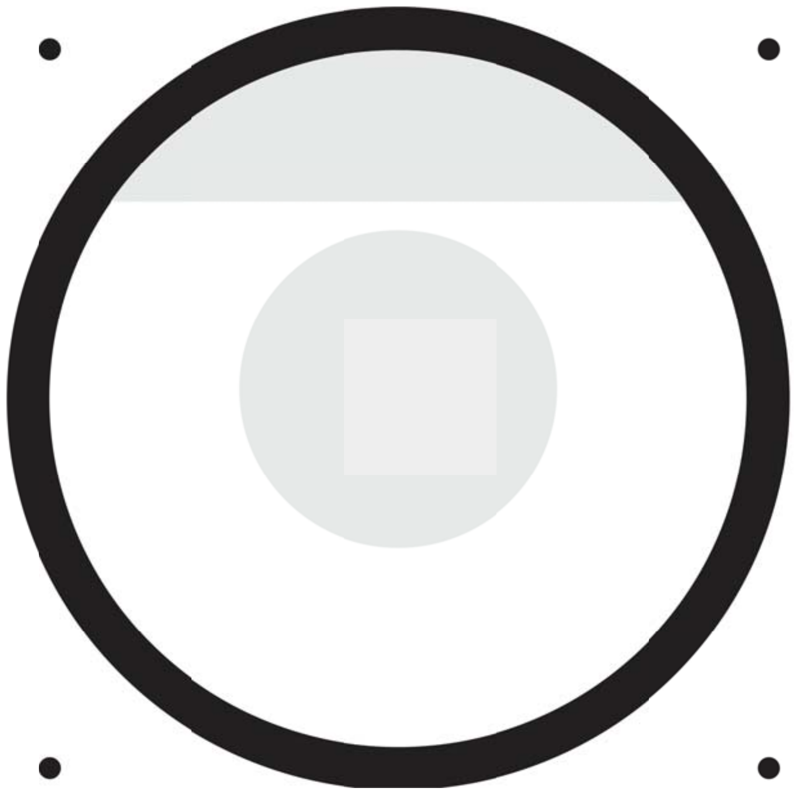


Figure 10. Square poster board with 37 cm steering wheel outline and dots to facilitate alignment in data processing.

Hubs and spokes. Center hubs of the steering wheel were provided in small (10 cm in height), medium (15 cm in height), and large sizes (20 cm in height). Various shapes were provided: circles, squares, ovals and rectangles (see ***Figure 11***). All hubs were grey in color. Spokes of the steering wheel were also provided in various shapes. Some shapes provided resembled those of current production cars, while others were non-traditional shapes (see ***Figure 12***). Spokes were colored black. Color-coding the wheel structure and controls by category allowed shapes to be distinguished when being analyzed in Adobe Photoshop. For example, radio controls were colored dark blue, which made them easy to separate from cruise control functions, which were colored orange, both of which could be distinguished from the black spoke on which they were placed. See ***Table 3*** for all control colors. Controls labeled “modal” are general functions like “up” and “down” that serve different purposes depending on the mode of the system. For example, in “Radio” mode, the up and down buttons control the FM radio tuning, but in “iPod” they become song “next” and “previous.” “Basic” controls are functions that are basic controls for vehicles, such as windshield wiper speed or windows up and down.

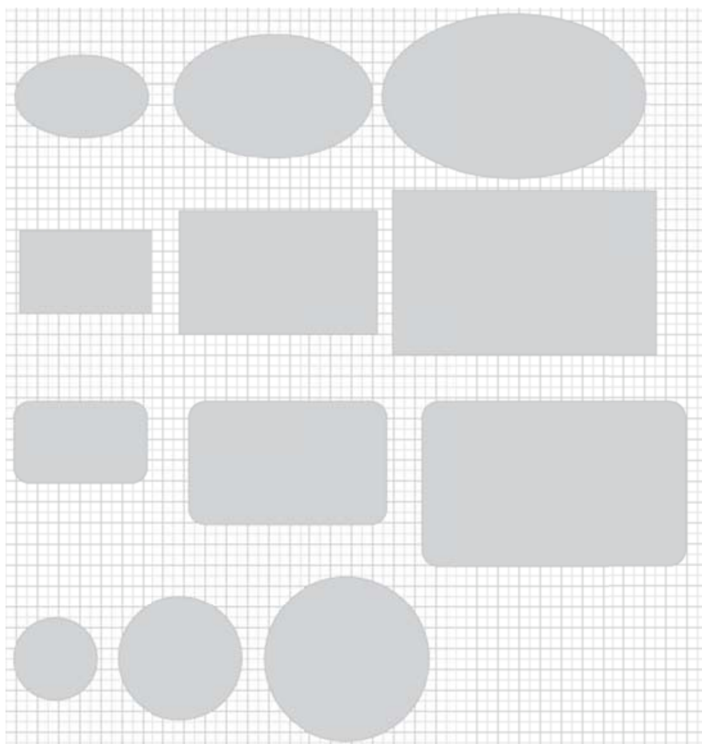


Figure 11. Pre-cut hubs provided to participants.

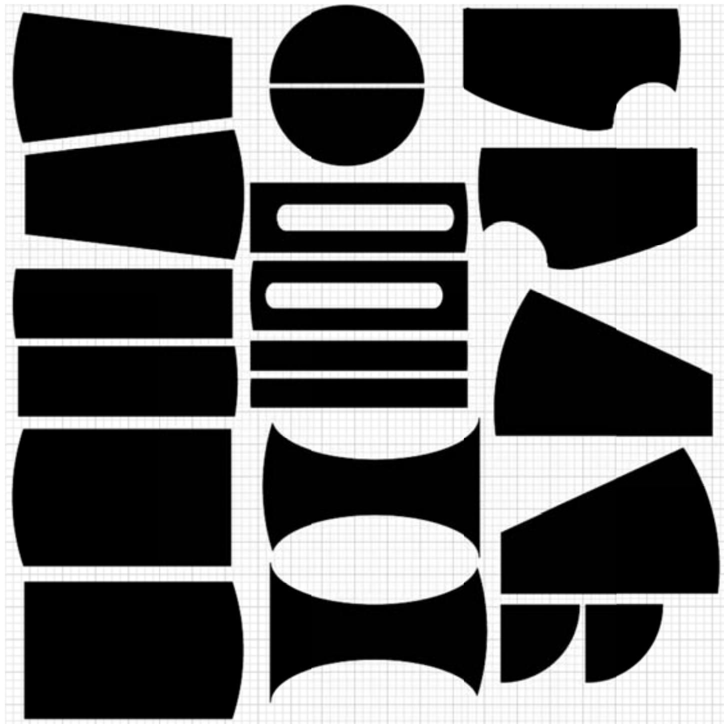


Figure 12. Pre-cut spokes provided to participants.

Table 3. Color-coding by function category.

Category	**Provided Functions**	**Color**
Radio	Volume Up Volume Down Next Track Previous Track Randomize song order	Dark Blue
Cruise Control	On Off Set Resume Accelerate Decelerate	Orange
Climate Control	Temperature Fan speed Air distribution	Yellow
Performance Control	Suspension stiffness Engine tuning	Purple
Navigation	Select destination Map settings	Green

Basic	Windshield wiper speed Wiper fluid Blinkers Head lights High beams	Pink
Other	Multimodal	Red
Spokes	---	Black
Hubs	---	Grey

Function Options. Possible functions were provided to the participant on individual pieces of foam board, which allowed participants to easily pick up and move the functions around their preferred design. Functions included radio volume up and down, climate control temperature, navigation functions, suspension settings, cruise control, etc. For a full list of functions, please see Appendix D. For data analysis, the functions were also color coded by group. ***Figure 13*** shows the colors of each type of function.

Control Options. Participants were able to choose the size and shape of the controls for the functions by selecting from pre-cut, color-coded cardboard shapes (***Figure 14***). Small sizes were 1 cm in diameter, medium were 2 cm, and large were 3 cm. Six pre-cut, basic geometric shapes were provided: square, rounded corner square, circle, oval, rectangle and rounded corner rectangle. All pre-cut shapes had a small dot printed on them to indicate the center of the item, which was used in data analysis. See ***Figure 13*** for all shapes provided to participants.

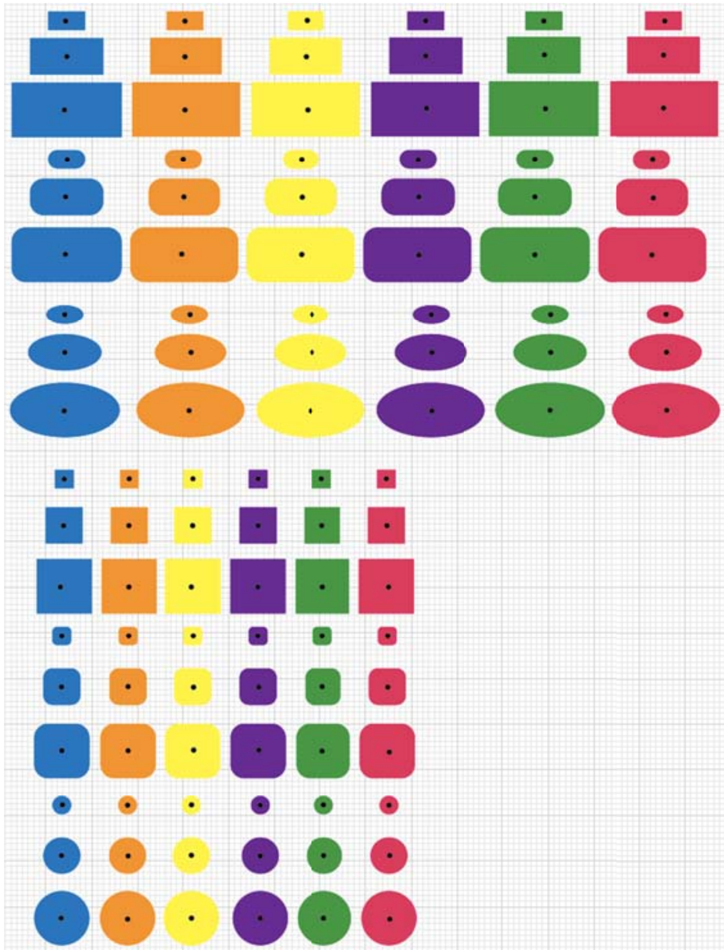


Figure 13. Pre-cut control shapes provided to participants.

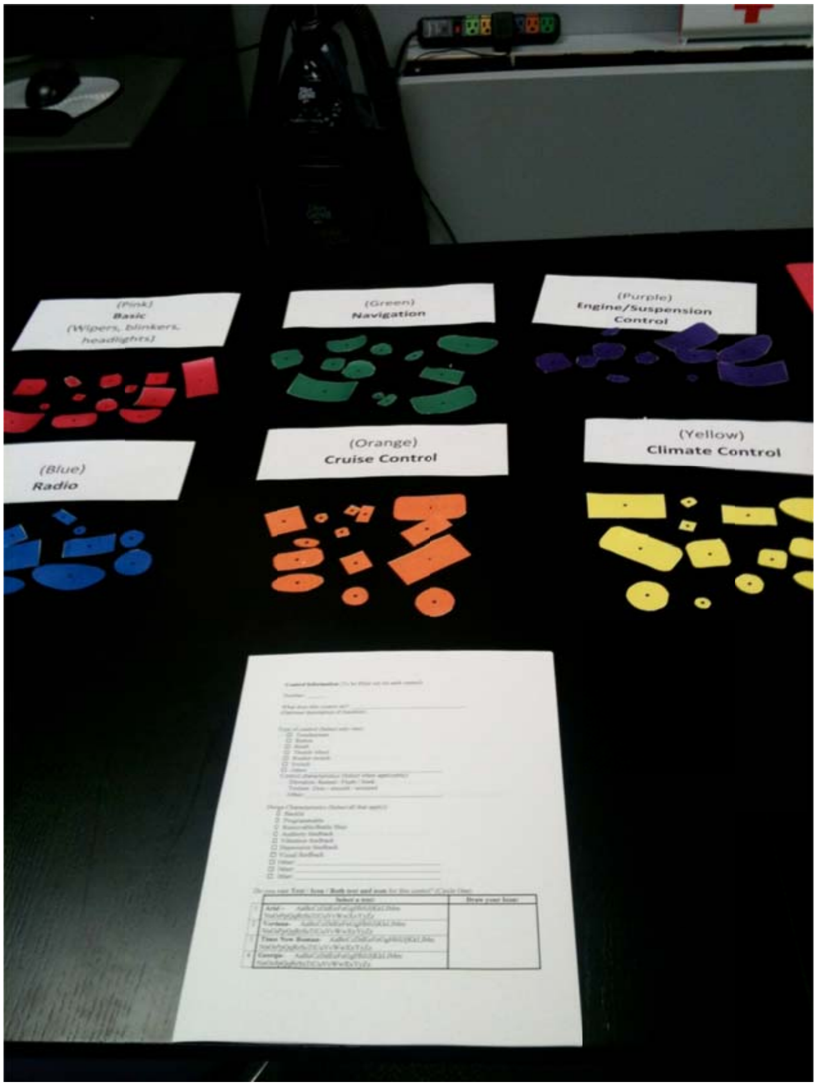


Figure 14. Close-up image of table set up with shapes and color coding.

Participants were allowed to modify any of the pre-cut shapes (i.e., round the edges of a square, make the square smaller, etc.) or cut their own shapes if the pre-cut shapes did not suit their design. All new shapes were color-coded red in order to distinguish them from the pre-cut shapes provided. After the participants completed their own design, they answered questions about each function. A sheet of paper with design characteristics was provided for each control the participant chose (See Appendix E). For example, if the participant chose five buttons, he/she completed five forms (one for each control) to fill in the design characteristics for each of those buttons. This form allowed participants to indicate functionality (i.e., button, touchscreen, knob, etc.) and design characteristics such as backlighting, text and icons. Four text fonts (two serif and two san serif) were chosen because these texts are familiar, easily read, and attractive based on a study by Bernard, Lida, Riley, Hackler and Janzen (2002).

Other materials. A Cannon SLR camera was used to take a picture of each participant's steering wheel. Adobe Photoshop CS6 and Statistical Package for the Social Sciences (SPSS) were used for analyses. Adobe Illustrator CS6 was used to create the suggested prototypes.

Procedure

Participants were pre-screened for age, gender, a valid driver's license, more than two years of driving experience, and for students' university major. After providing consent, participants were shown the video explaining CU-ICAR, Deep Orange and the Deep Orange 1 vehicle in order to give participants, who may have been unfamiliar with Deep Orange 1, context for the study. Next, participants were encouraged to examine the photographs of example steering wheels on the wall in front of them.

Participants were shown and read a list of all of the functions of the Deep Orange 1 concept vehicle, as provided by the Deep Orange engineers. (Note: The script read by the researcher can be seen in Appendix F. Any functions that participants were not familiar with were explained in detail. Participants were instructed that each function had to be placed on the steering wheel, center stack, or stalks. Participants were told not to select other locations like doors or gauge clusters. Functions that participants decided to locate on the center stack or stalks were noted and set aside. Only the functions placed on the steering wheel were analyzed for the current study. Participants were given the poster board with the steering wheel outline. (Note: Participants were instructed not to place controls in the grey areas representing the air bag and gauge cluster, since this would not comply with current government regulations.) Then, participants designed the structure of the steering wheel by picking the shape, size and number of spokes along with the shape and size of the center hub. Next, they selected the functions and placed the colored cardboard control shapes on the cardboard wheel outline. An example of a participant's final design including the hub, spokes and controls can be seen in ***Figure 15***.

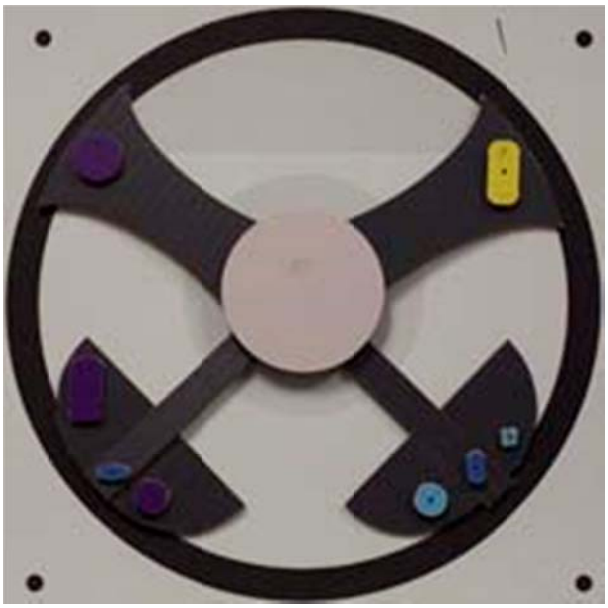


Figure 15. Example of one participant's complete design.

Then, the participants completed a form for each separate control they had chosen. Each form contains several items with check boxes for specific design characteristics such as backlighting, texture, type of control, auditory feedback, text and icon, etc. Participants began by selecting the type of control (i.e., button, rocker switch, knob, etc.). Then participants selected from several options of the control's design such as texture, backlighting, and visible feedback. Lastly, participants selected the type of label, text or icon, for the control, and if participants elected to use an icon, they were asked to draw the icon. The participant selected the options he /she desired for that control or chose the "other" option(s) if any option was not specifically listed (see Appendix E). These design sheet forms were numbered to correspond with the control number on the paper prototype. Finally, in order to understand why participants made the selections they did, they were asked a short series of questions regarding their design decisions and reasoning, which were recorded by the researcher (see Appendix G).

Participants were encouraged to proceed through the study in the order listed above, but occasionally participants revised their design as they made their selections. Revisions to the design were allowed at any point in the process; however, only the final design was analyzed.

Results

Data Analysis Process

Images were used to create visualized data of the steering wheels that the participants designed. Descriptive statistics were used to paint a broad picture of participant demographics as well as some types of participant selections such as frequency of function selection and type of control selected. Pearson correlations were used to understand the relationship between variables like date and number of voice control functions. Chi squares were used for many variables to determine if group belonging determined which categorical variables participants selected for their design. Unprocessed pictures of each participant's designs can be seen in Appendix H.

Unanticipated Participant Responses

Because this study is exploratory, it is worth noting participant responses that were unexpected. As mentioned above, one of the control categories recorded was "modal" controls. However, this was not included in the initial study proposal. The researcher did not expect this category, but the first two participants included these features, so this category was added. Initially, paddle shifters were not to be included in the study because they were considered primary driving controls (controls that were critical to the vehicle's operation). The first engineer to participate in the study promptly asked to include paddle shifters, so these controls were added to the study as well. Because voice control was a feature that was new to the public when the study was proposed, it also was not included, but participants often requested this feature, so the data were included. All of these added features were recorded beginning with the first participant who requested it. Neither modal controls nor voice controls were specifically offered to participants at any time but were often requested and noted when requested. Paddle shifters were specifically offered to participants because including them in the engineering design has implications critical to the initial vehicle concepting. Additionally, users were never prompted to decide between a round steering wheel or a non-round steering wheel. However, several participants requested this feature and their non-round designs were recorded.

While most participants enthusiastically participated in all parts of the study, some participants were hesitant to complete the section of the study that included drawing icons for the controls. Some participants seemed embarrassed by their drawings, while some refused to draw icons and would select text labels for controls to avoid this task. Some participants would select text labels after a short time trying to think of possible icons, but were unable to think of the “normal” or “standard” icon. For this reason, the data in this paper regarding labeling should be considered suggestions rather than fact.

While the technology affinity questions were not a primary concern of the study, it is of interest to note that the engineers displayed a generally lower level of trust in technology than other participant groups (Appendix B). It is possible that when asked about “technology”, engineers include their thoughts on the complex technologies they use like computer aided design programs and other specialty software and hardware. In contrast, when non-engineers are asked about “technology”, they rate opinions of technologies they use the most, like cell phones and common software programs. This group difference and engineer distrust would be of interest for future studies.

Steering wheel structure

To create an overall picture of the shape of participant-designed wheel structure and locations of controls, pictures of the steering wheels were made transparent and overlaid. First, the structure of the spokes and hubs were analyzed across and between groups (***Table 7***). The number of spokes selected varied slightly between groups. Participants were also allowed to note if they preferred the steering wheel to be a shape other than round (i.e., butterfly style, flattened top, flattened bottom, etc.). Statistics on structure variations between groups can be seen in ***Table 4***.

Table 4. Wheel structure variation.

	Total	Generation-Y	Engineer	Baby Boomer
2 spokes	20%	20%	0%	47%
3 spokes	60%	60%	60%	48%
4 spokes	20%	20%	40%	5%
Non-round	18%	10%	27%	20%

Control Selection and Location

Number of controls selected. The number of controls selected was compared to age, gender and group. None of these variables showed a significant effect on the number of controls participants elected to put on their steering wheel. The average number of functions participants in each group chose to place on the steering wheel can been seen in ***Table 5***.

Table 5. Average number of functions located on the steering wheel.

	All	Generation-Y	Engineer	Baby Boomer
M	15.9	14.8	14.9	17.9
SD	7.1	6.6	5.7	8.3
Range	1 - 34	4 - 31	1 - 22	9 - 34

Vehicle location placement. Each control had to be placed in a location. The following table (***Table 6***) shows where participants chose to place each control: steering wheel, center stack or stalks. The most frequently selected location for a function is shaded grey, bold, and italic across the three age groups. Also, only three participants requested that at least one control be located on the back of the steering wheel. (These were counted as being on the steering wheel and, therefore, would be reflected in the first column.) Chi-square tests were used to determine if the participant groups chose to place controls in the same location. Only significant Chi-square tests are shown in ***Table 6***.

Table 6. Participant function location preferences (in percentages)*.

	Steering Wheel				Center Console				Stalks				**Chi Square *p* value
	All	GenY	Eng	BB	All	GenY	Engr	BB	All	GenY	Eng	BB	
Seat adjustments	9	5	7	15	89	95	87	85	2		7		
Climate ctrl temperature	13		13	25	85	95	87	75	2	5			
Climate ctrl fan speed	13		7	30	85	95	93	70	2	5			0.036
Climate Ctrl fan location/mode	11		7	25	89	100	93	75	100	100	100	100	0.033
Driver window up/down	11	20	13		85	80	80	95	4		7	5	
Passenger window up/down	4		7	5	95	100	93	90	2			5	
Seat climate Ctrl	11	15		15	89	85	100	85	100	100	100	100	
Sunroof ctrl	5	10		5	95	90	100	95					
Engine on/off	15	30	7	5	80	70	80	90	5		13	5	
Horn	100	100	100	100									
Cruise ctrl on/off	58	50	47	75	5		13	5	36	50	40	20	
Cruise ctrl set	64	50	53	85	5		20		31	50	27	15	0.006
Cruise ctrl increase speed	65	55	53	85	4		13		31	45	33	15	0.038
Cruise ctrl decrease speed	65	55	53	85	4		13		31	45	33	15	0.038
Cruise ctrl resume	64	50	53	85	4		13		33	50	33	15	0.023
Headlights auto/on/off	5	5	13		13	10	7	20	78	80	80	75	
High beams on/off	11	5	13	15	2			5	87	95	87	80	
Blinkers/indicators	5	5		10	2			5	93	95	100	85	
Hazard lights	5	10	7		60	60	53	65	35	30	40	35	
Dome light auto/on/off	2		7		82	75	80	90	15	25	13	5	
Fog lamps on/off	2			5	29	15	33	40	69	85	67	55	
Windshield wipers auto/on/off	5			15					95	100	100	85	
Windshield wipers speed/inter.	7			20	2	5			91	95	100	80	0.057

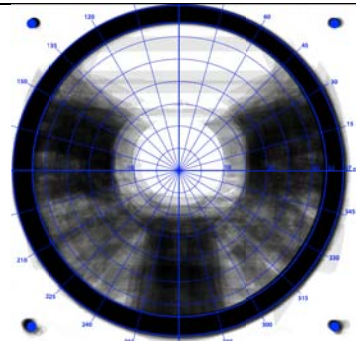
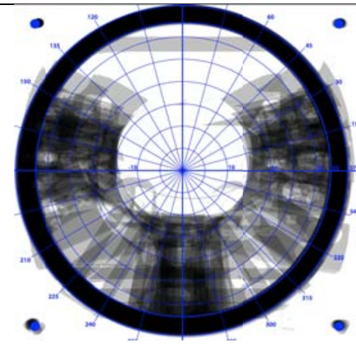
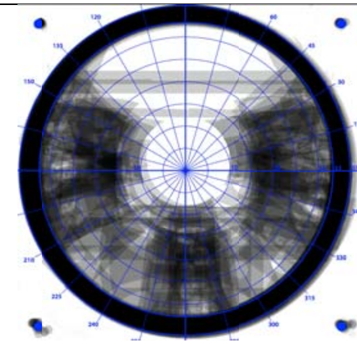
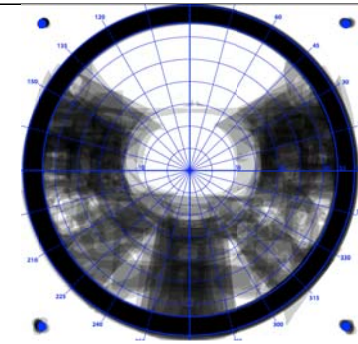
Windshield wiper fluid/clean	4			10	2		7		95	100	93	90	
Windshield defrost	5	5		10	73	70	73	75	22	25	27	15	
Rear window defrost	5	5		10	85	90	93	75	9	5	7	15	
Door lock/unlock	7	15	7		89	85	87	95	4		7	5	
Suspension adjustments	13	10	33		78	70	67	95	9	20		5	0.010
Engine adjustments	24	25	40	10	67	60	53	85	9	15	7	5	
Left & right mirror adjust	9	10	13	5	80	70	80	90	11	20	7	5	
Traction ctrl on/off	16	15	33	5	71	65	60	85	13	20	7	10	
Trunk pop					87	90	73	95	13	10	27	5	
Hood pop					82	80	67	95	18	20	33	5	
Garage door/gate open/close	4	10			91	80	93	100	4	5	7		
Torque boost	42	55	40	30	40	20	47	55	16	20	13	15	
Stereo on/off	33	30	20	45	67	70	80	55					
Volume up/down	89	100	87	80	11		13	20					
Song rwd/fwd	40	40	47	35	58	60	53	60	2			5	
Song next/prev	69	85	87	40	29	15	13	55	2			5	0.012
Song repeat/shuffle	20	25	13	20	78	75	87	75	2			5	
Scan radio	38	30	33	50	60	70	67	45	2			5	
Song play/pause	67	65	87	55	31	35	13	40	2			5	
Song mute	64	55	73	65	35	45	27	30	2			5	
Radio presets	38	25	33	55	62	75	67	45					
Equalizer adjustments	9	5		20	89	95	100	75	2			5	
Stereo mode	45	50	40	45	53	50	60	50	2			5	
Answer/hang up phone	69	70	80	60	29	30	13	40	2		7		
Browse contacts	35	25	47	35	62	70	47	65	4	5	7		
Compose & send text message	35	30	33	40	64	65	67	60					
Dial phone number	40	25	40	55	60	75	60	45					

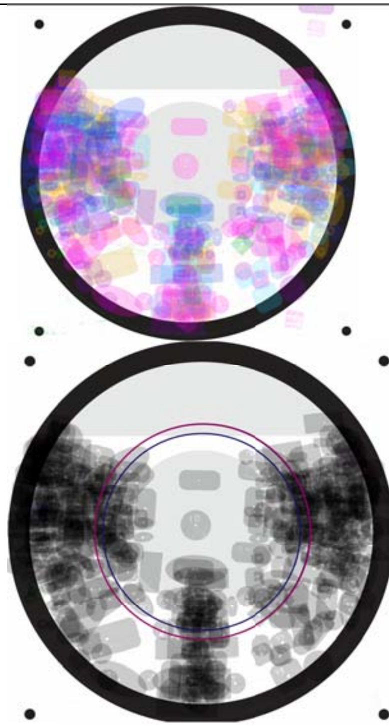
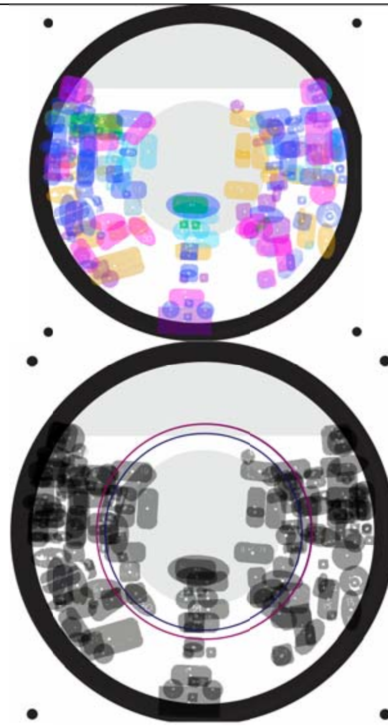
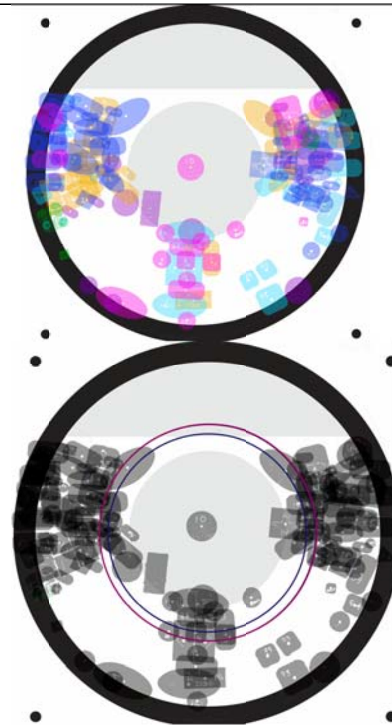
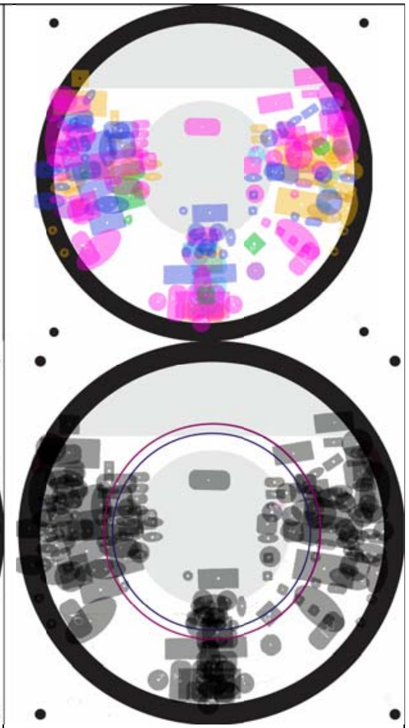
Send location to others	9			25	87	95	100	70	2			5	0.022
Cell phone holder/charging port					98	95	100	100					
"Favorite"/"like" song	25	35	13	25	71	65	87	65	2			5	
Playlist generation	13	10	7	20	84	85	93	75	4	5		5	
Browse by artist/playlist/song/genre	31	40	20	30	65	55	80	65	4	5		5	
Internet functions	15	5	7	30	85	95	93	70					0.048
Navigation system functions	29	15	33	40	69	85	67	55	2			5	
Traffic updates	15	5	7	30	84	95	93	65	2			5	
Download media content	11	5		25	87	90	100	75					0.040
Dashboard configuration	2			5	91	85	100	90	2	5			
Vehicle configuration	4	5		5	95	95	93	95	2		7		
Avatar action button	13	20	13	5	84	75	80	95	2		7		
Avatar on/off	9	15	7	5	87	80	87	95	2		7		
Store media content	13	10		25	87	90	100	75					
Walkie-talkie	36	35	40	35	62	60	60	65	2	5			

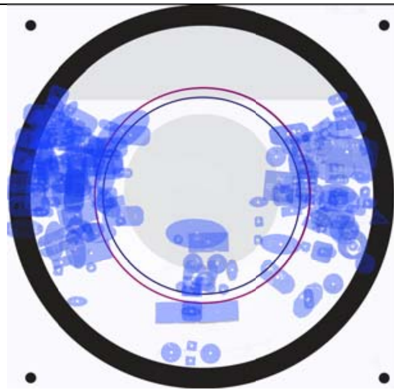
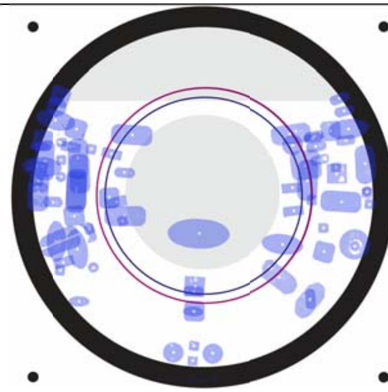
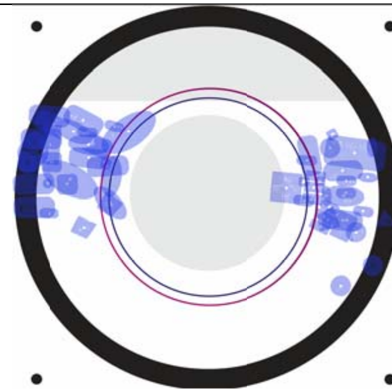
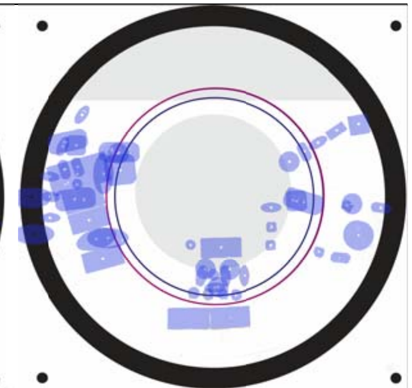
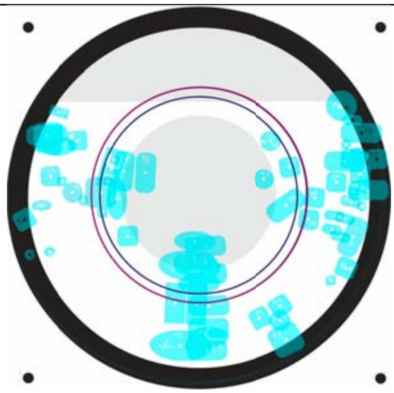
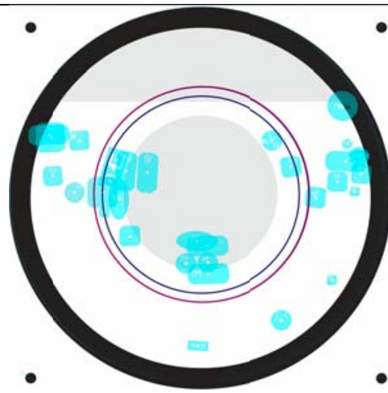
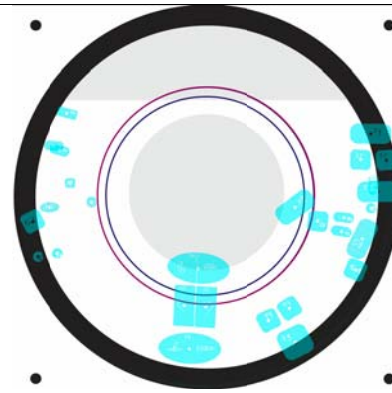
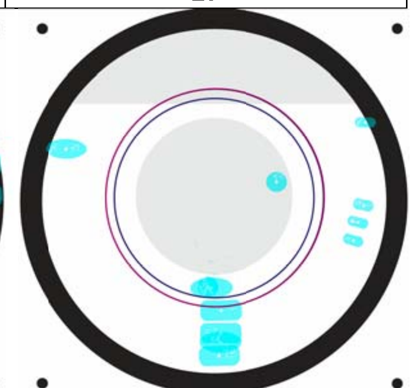
* All results are percentages and blank cells are 0%.
** Chi Square was performed on all functions. Only significant *p* values are listed.
***Abbreviations: All- all groups. Gen-Y- Generation-Y. Eng- Engineer. BB- Baby Boomer

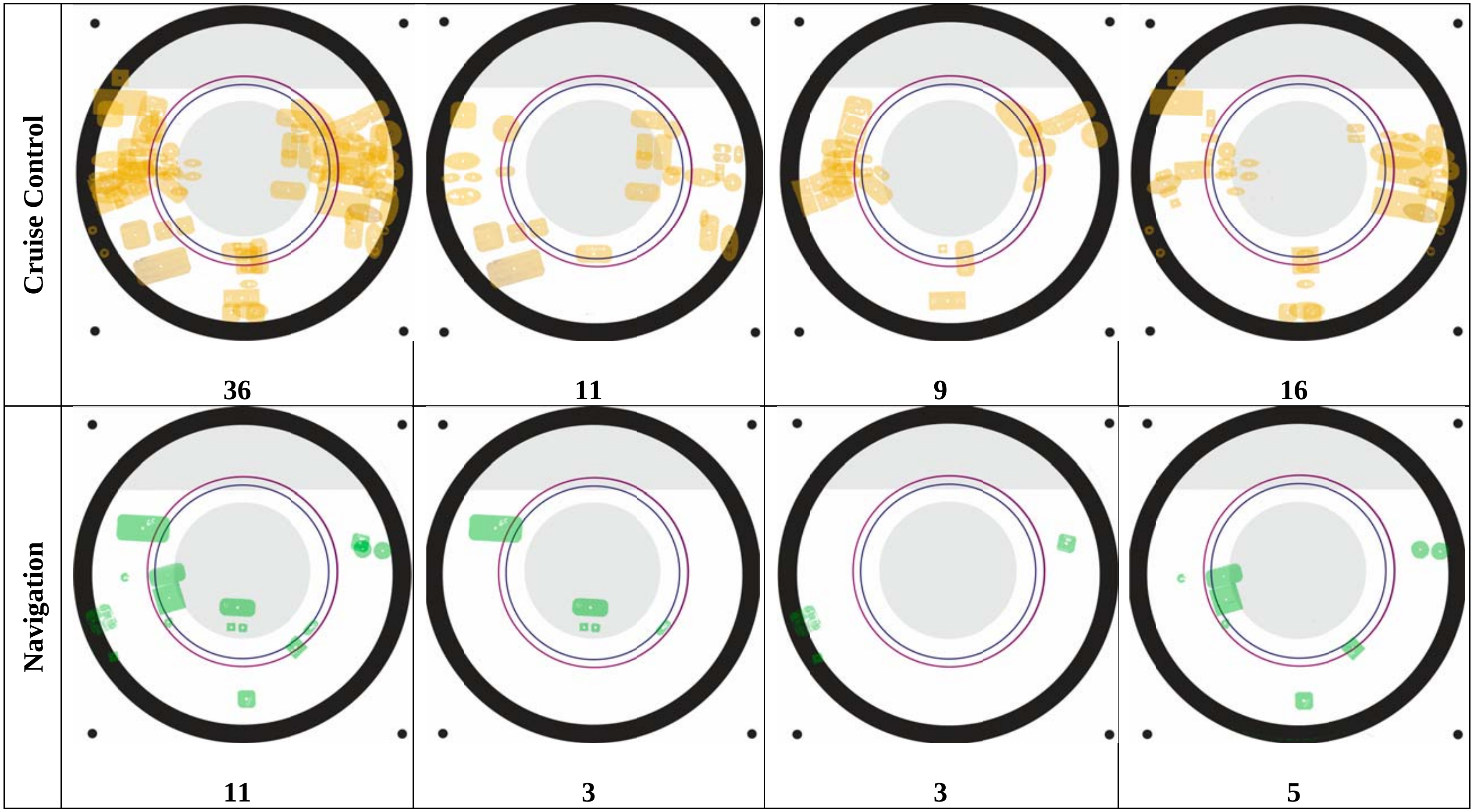
Control Placement on the Steering Wheel. Next, images of all controls on the participants' steering wheel designs were layered across all groups as well as between groups (***Table 7***). This allowed for a picture of where participants tended to place controls on their steering wheels. Because function categories were color coded, they were able to be separated and analyzed. Below is a table of figures of each control category across and between groups (***Table 7***). The pink and blue rings seen in ***Table 6*** represent the average thumb reach (digit 1 length) of males (blue), *M* = 6.97cm, and females (pink), *M* = 6.35cm, as recorded in Greiner's Hand Anthropometry of U.S. Army Personnel (1991).

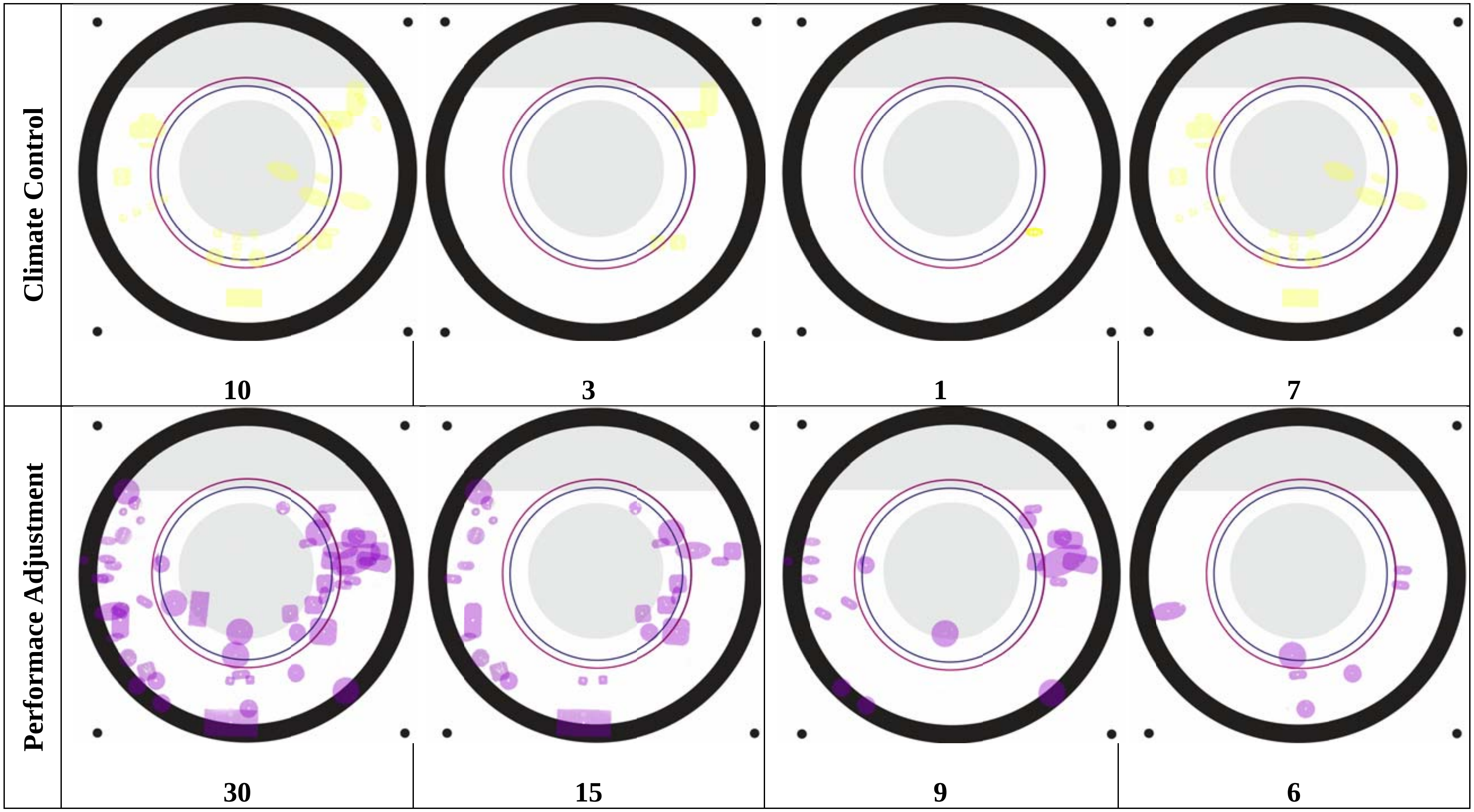
Table 7. Wheel structures and control category by group (including number of participants represented in each image).

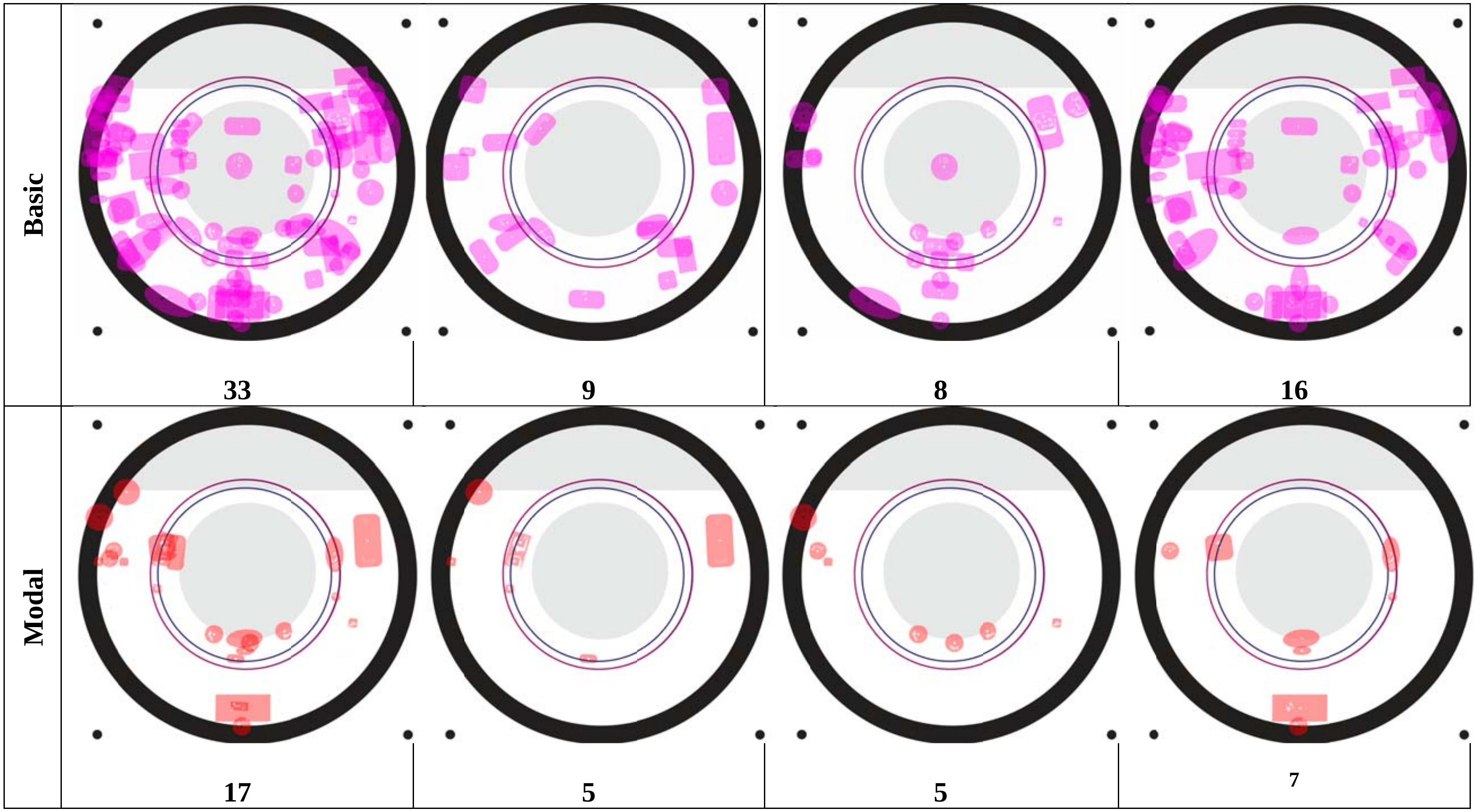
	All Groups	Generation-Y	Engineers	Baby Boomer
Structure	 **55**	 **20**	 **15**	 **20**

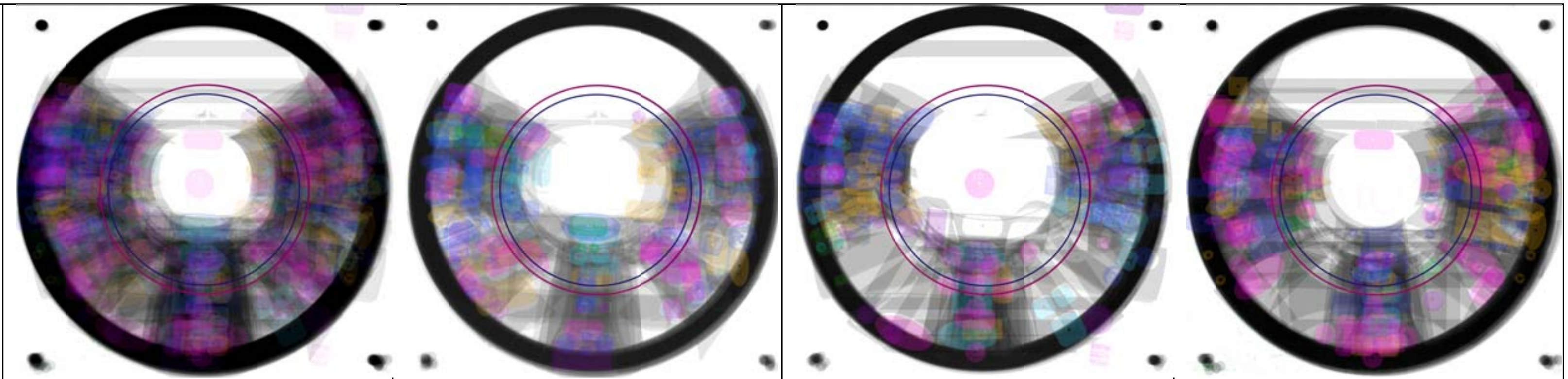
All Controls	 **54**	 **20**	 **14**	 **20**

Radio	 **50**	 **20**	 **13**	 **17**
Phone	 **36**	 **16**	 **17**	 **8**


Cruise Control
36
11
9
16
Navigation
11
3
3
5


Climate Control
10
3
1
7
Performace Adjustment
30
15
9
6


Basic
33
9
8
16
Modal
17
5
5
7

All				
	55	20	15	20

Manual Transmission Control. Participants were asked to select whether they would prefer a standard H-pattern gearshift or paddle shifters for a manual vehicle. This question was added half way through the study, so that there were at total of 30 participants able to answer the question. If participants did not know what paddle shifters were, it was explained using the display of example steering wheel pictures. Of the 30 participants who were asked this question, 53%said they would prefer paddle shifters to an H-pattern gearbox. However, it should be noted that this question was not distributed evenly across groups. Of the 14 engineers asked, 71% said they would like this feature. Of the 11 Baby Boomers asked, 27% said they would like this feature. Only five Generation-Y participants were asked this question, but 60% said they would prefer paddle shifters. See ***Table 8***.

Table 8. Participant preference for paddle shifters.

	Total	Generation-Y	Engineer	Baby Boomer
N asked the question	30	5	14	11
Paddle Shifters	53%	60%	71%	27%

Control Design Characteristics

Voice control. The researcher recorded whether participants preferred the function to be voice controlled. When the study design was in the development phase, Apple's Siri was not available on the iPhone. Coincidentally, Siri became available during the first week of data collection (Apple, 2011). The last week of data collection, it was announced that Siri would be installed in some popular vehicles in the United States (Fox News, 2012). Because of this accidental time line, the number of controls participants preferred to be voice controlled was also plotted against their participant number, which corresponded to the order the data was collected (so 1 was the earliest participant and 55 the last) creating a timeline; however, this did not reveal a significant correlation. Table 9 shows how many participants requested a steering wheel function be voice controlled. For example, 19 participants elected to put a "compose & send text message" control on the steering wheel, and all 19 of those participants (100%) wanted that function to be voice controlled.

Table 9. Number of participants who requested a function be voice controlled.

Function	Percent of all 55 participants	Percent of participants who placed the control on the wheel and wanted it to be voice controlled	Percent of all participants per group*		
			GenY	Engr	BB
Compose and send text message	35	100	25	27	50
Browse contacts	24	65	10	20	40
Dial phone number	24	54	5	20	45
Answer/hang up phone	22	31	5	13	45
Navigation system functions	20	65	5	20	35
Browse by artist/playlist/song/genre	16	50	10	7	30
Internet functions	15	100	5	7	30
Song next/prev	11	16	5	13	15
Walkie-talkie	11	32	0	7	25
Stereo on/off	9	28	5	7	15
Song repeat/shuffle	9	45	5	7	15
Song play/pause	9	14	5	7	15
Stereo mode	9	20	0	7	20
Send location to others	9	100	0	0	25
Favorite/like song	9	38	0	7	20
Playlist generation	9	71	0	0	25
Traffic update	9	56	0	7	20
Download media content	9	83	0	0	25
Store media content	9	100	0	0	25
Song rewind/forward	7	18	5	7	10
Volume up/down	5	6	5	7	5
Scan radio	5	15	5	0	10
Song mute	5	9	5	7	5
Radio presets	5	14	0	7	10
Equalizer Adjustment	4	40	0	0	10
Avatar action	4	29	0	7	5
Avatar on/off	4	50	0	7	5
Performance controls	2	8	0	0	5

* Abbreviations: All- all groups. Gen-Y- Generation-Y. Eng- Engineer. BB- Baby Boomer

For each function placed on the steering wheel, participants were asked a series of questions about design characteristics of each control, including options such as type of control, texture, elevation, and visual feedback.

Table 10 shows what types of controls were selected most frequently for each function. Chi Squares analyzing the effect of group belonging on type of control selected for each function only showed significance for one control, *browse by artist / playlist / song / genre* (p= 0.023, n= 18). Fifty percent of Generation-Y who selected the door lock/unlock feature opted for a button, while the other half opted for “other”; 67% of engineers who chose this feature opted for a button, and 100% of Baby Boomer selected a button. The design characteristics participants selected were tested to see if there were preference differences between groups and results seen in the rightmost column of ***Table 13***.

Table 10. Types of controls for each function on steering wheel, in percentage of participants who placed the function on the steering wheel*.

	Button				**Knob**				**Thumbwheel**				**Rocker switch**				**Switch**				**Other**			
	** All	Gen Y	Eng	BB	All	Gen Y	Eng	BB	All	Gen Y	Eng	BB	All	Gen Y	Eng	BB	All	Gen Y	Eng	BB	All	Gen Y	Eng	BB
Seat adjustments													80	100	100	67					20			33
Climate ctrl temperature	14			20					14		50		14			20					71		50	60
Climate ctrl fan speed	14			17									29			33					57			50
Climate Ctrl fan location/mode													17			20					50			60
Driver window up/down													83	75	100									
Passenger window up/down													100		100	100								
Seat climate Ctrl	17			33									33	67							50	33		67
Sunroof ctrl													33	50							33	50		
Engine on/off	100	100	100	100																				
Horn	100	100	100	100																				
Cruise Ctrl on/off	75	60	71	87									13	20	14	7					13	20	14	7
Cruise ctrl set	57	50	63	59									29	20	25	35					14	30	13	6
Cruise ctrl increase speed	17		25	24									58	45	63	65		9			19	36	13	12
Cruise ctrl decrease speed	17		25	24									61	45	75	65		18			19	36	13	12
Cruise ctrl resume	49	40	50	53									31	20	38	35					17	30	13	12
Headlights auto/on/off	67		50																					
Highbeams on/off	100		100	133																				
Blinkers/indicators	67			100									33			50								
Hazard lights	100	50	100														33	50						
Dome light auto/on/off	100		100																					
Fog lamps on/off	100			100																				
Windshield wipers auto/on/off	33			33									33			33					67			67
Windshield wipers speed/intermittent				0									75			75					50			50
Windshield wiper fluid/clean	10			10																				

	0			0																				
Windshield defrost	100			150																				
Rear window defrost	100	100		100																				
Door lock/unlock	25		100										75	100										
Suspension adjustments	43	50	40		14		20		14		20						14	50			14		20	
Engine adjustments	46	60	33	50	15	20	17		8		17		8			50	8	20			15		33	
Left & right mirror adjust									20	50			40		50	100					40	50	50	
Traction ctrl on/off	89	100	80	100									11		20									
Trunk pop																								
Hood pop																								
Garage door/gate open/close													50	50										
Torque boost	70	64	83	67									9			33	22	36	17		4		17	
Stereo on/off	83	83	100	78									6			11					11	17		11
Volume up/down	10	15	8	6	2	5			8	10	8	6	45	30	62	50					35	40	23	38
Song rwd/fwd	32	38	14	43									45	38	71	29					23	25	14	29
Song next/prev	29	18	31	50					5	12			42	47	46	25					24	24	23	25
Song repeat/shuffle	82	80	100	75									9		50						9	20		
Scan radio	43	50	60	30									38	33	40	40					14	17		20
Song play/pause	62	54	77	55					5	8	8		8		8	18	3	8			22	31	8	27
Song mute	69	82	82	46					6	9	9		11		9	23					14	9		31
Radio presets	38	20	40	45	5	20							43	40	20	55					14	20	40	
Equalizer adjustments	60			75									20			25					20	100		
Stereo mode	68	60	83	67	4	10							20	20	17	22					8	10		11
Answer/hang up phone	76	71	83	75									13	7	17	17	3			8	11	21		8
Browse contacts	68	40	57	100					5		14						5			14	26	60	29	
Compose & send text message	84	83	60	100													5			13	11	17	20	
Dial phone number	82	80	100	73									18		17	27	5			9	5	20		
Send location to others	100			100																				
Cell phone holder/charging port																								
"Favorite"/"like" song	64	57	100	60																	29	43		20
Playlist generation	86	50	100	100																	14	50		

Browse by artist/playlist/song/genre	72	50	67	100											33						22	50		
Internet functions	100	100	100	100																				
Navigation system functions	88	100	60	100												13					13		40	
Traffic updates	100	100	100	100																				
Download media content	100	100		100																				
Dashboard configuration																								
Vehicle configuration																					10	100		100
Avatar action button	86	75	100	100									14	25										
Avatar on/off	80	67	100	100																				
Store media content	71	50		80																				
Walkie-talkie	80	43	100	100									5	14							10	29		

* All data is in percentages and is a percentage of participants who placed the control on the steering wheel, not a percentage of all participants. Blank cells represent 0%.

** Abbreviations: All- all groups. Gen-Y- Generation-Y. Eng- Engineer. BB- Baby Boomer

Open-ended questions

Participants were asked two open-ended questions: “What were your main considerations in creating your design, and what was most important to you?” and “How did you decide what functions you wanted on the steering wheel?” Participants’ responses were recorded verbatim and then were copied into a single document that was analyzed using a website tool that creates infographics, www.wordle.net (see Appendix I for more details). The frequency of the word dictates its size in the image. For example, words with higher frequency counts are displayed larger than words with smaller frequency counts. Words such as *and, with, were,* are not counted. Participant responses to “What were your main considerations in creating your design and what was most important to you?” can be seen in *Figure* 16 and “How did you decide what functions you wanted on the steering wheel?” can be seen in *Figure 17*.

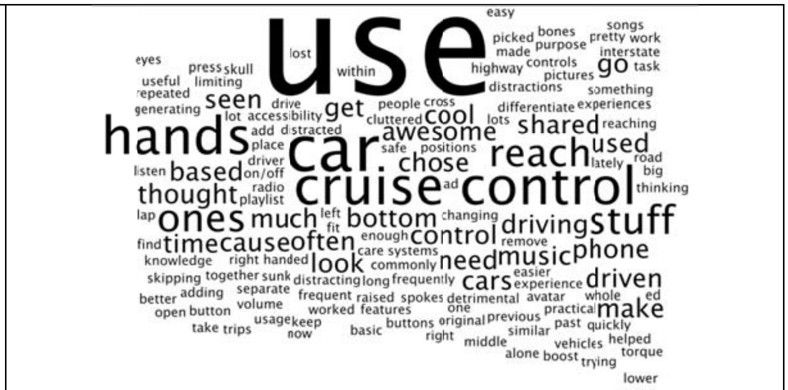
<table>
<tr><td>All Groups</td><td>
</td></tr>
</table>

<table>
<tr><td>Generation-Y</td><td>
</td></tr>
<tr><td>Baby-Boomer</td><td>
</td></tr>
<tr><td>Engineer</td><td>
</td></tr>
</table>

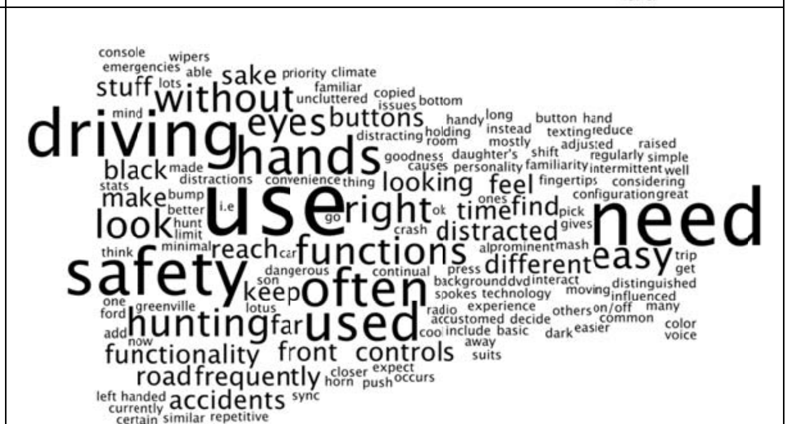
Figure 16. Participant responses to “What were your main considerations in creating your design and what was most important to you?”

<table>
<tr><td>All Groups</td><td>
</td></tr>
</table>

Generation-Y



Baby-Boomer



Engineer

Figure 17. Participant responses to the question “How did you decide what functions you wanted on the steering wheel?”

In addition to the open-ended questions, participants were asked two questions regarding their design choice. On a scale of 1 to 5, where 1 is *strongly disagree* and 5 is *strongly agree*, participants were asked to choose the appropriate number on the scale to correspond with the statements: (1) “I considered aesthetics when creating my design”; (2) “ I considered functionality when creating my design.” Group belonging did not affect participant responses. Participants tended to agree or strongly agree with both statements regardless of group. See ***Table 11***.

Table 11. Participants' responses to aesthetic and functionality choices on a scale of strongly disagree (1) to strongly agree (5).

	Generation-Y			Engineer			Baby Boomer		
	M	*SD*	Range	*M*	*SD*	Range	*M*	*SD*	Range
I considered aesthetics when creating my design.	4.2	0.99	2 - 5	4.4	0.63	3 - 5	4.2	0.93	2 - 5
I considered functionality when creating my design.	4.9	0.37	4 - 5	4.7	0.49	4 - 5	5.0	0.00	5 - 5

Prototypes

Because this project was motivated by the development of the Deep Orange concept vehicle, one requirement of the committee included two prototypes for each age group for consideration in future Deep Orange vehicles. These prototypes were largely based on aggregated images for each group and functions most frequently chosen by groups. While trends can be determined from the visual and majority preference data, creating the prototypes required a degree of artistic liberty. The prototypes were created in the following manner. First ***Table 7*** was used to determine control location. The images in Table 7 were made from layered, translucent images of each participant's design to figure out where wheel structure and controls were most commonly placed. The locations that are darkest in the image are the positions participants most frequently chose to locate a given type of control. The prototypes started with the structure (color-coded black). The prototype structure was drawn where the image was darkest. The spokes were then made symmetrical from left to right, as they would be in a vehicle. Next, the functions that were selected by at least 50% of the participants were to be placed on the wheel. Using the translucent layers from the correct category (for example, volume up is a radio function, so the dark blue layers were used), a region was determined to fit all of the functions within that category. For example, if radio functions frequently appeared in the bottom left side of the left spoke, this is where all radio functions would be placed on the prototype. In addition, the type of control was selected by determining which control (i.e. button, rocker switch, etc.) was selected most often by participants. Labeling (i.e. text and icons) was also decided by what was most commonly chosen by participants. Additionally, other features like backlighting were decided by majority. All of these options and the percentage of participants who selected them are seen in ***Table 13***. This process was repeated for each of the most commonly selected functions, and the entire process was repeated for each group. The second version of the prototype for each group was expanded to include more of the structure commonly selected and functions selected by at least 40% of participants. The same process from the first prototype was used for the second prototype. Prototypes can be seen in ***Table 12***.

It is of note that while icon and text data is included in ***Table 13***, further data may be needed to determine the best design. Many participants elected to choose text because they were embarrassed to draw an icon. While participants were reminded that their drawing ability was not what was important to the study, many still shied away from the icons even when they expressed preference for this. This methodology should be changed in future studies to ensure data accurately reflects participants wants and needs rather than other variables. In the current data, it is interesting to note that Baby Boomers were more likely to use text labels than other groups. To provide a starting point for the current prototypes, the current labeling data was used, but further research and testing is needed.

For all groups, radio controls tended to be grouped on the left side of the wheel. Baby boomers included more radio controls than other groups. Engineers were the only group who placed cruise control more frequently on the left side of the wheel.   Phone functions were placed on the lower spoke, where they were most commonly located, except for the Baby Boomer two spoke design were they were located on the right side, as was also common. Groups that included performance adjustments located them on the right side, and this is reflected in the prototypes. Navigation was only chose for the over 40% Baby Boomer design, and was located on the left side, though more research should be done to determine the best location because placement of this control was inconsistent.

These prototypes were designed to reflect a general summary of the data for each and all groups. While this can be a starting point for future designs, other specifics from participant responses could also be utilized to create a full design. As always, prototypes should be tested with participants before implementation, preferably in a 3D environment.

Table 12. Prototype steering wheels based on composite user designs.

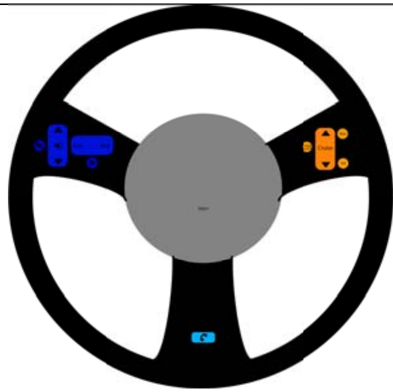
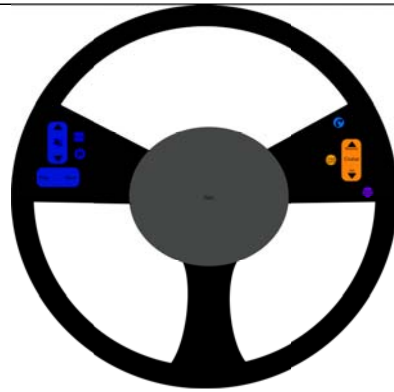
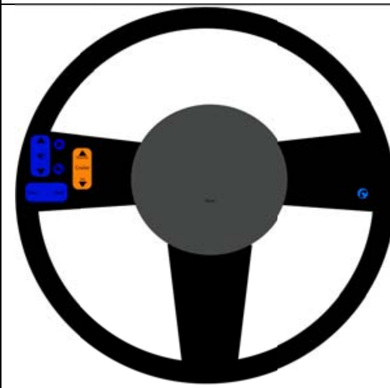
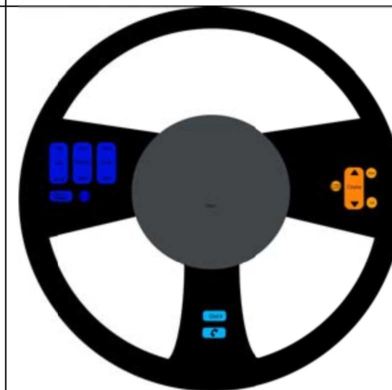
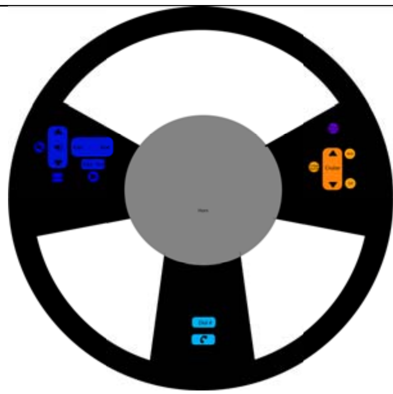
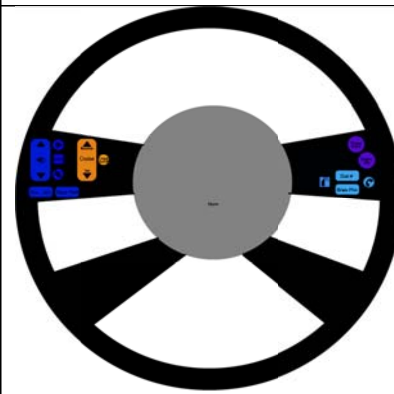
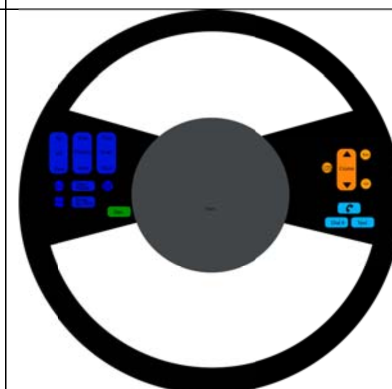
	All	Generation-Y	Engineer	Baby Boomer
Version 1				
Version 2				

Table 13. Characteristics for controls included in prototypes, by group.*

	All					Generation-Y					Engineer					Baby Boomer				
	Ctrl Type	**Elevation**	**Texture**	**Other**	**Label**	**Ctrl Type**	**Elevation**	**Texture**	**Other**	**Label**	**Ctrl Type**	**Elevation**	**Texture**	**Other**	**Label**	**Ctrl Type**	**Elevation**	**Texture**	**Other**	**Label**
Horn			100%					100%					100%					100%		
	B-100	Ra-57	Sm-49	Au-100	I-8 2	B-100	F- 55	Sm-84	Au-100	I- 85	B-100	Ra-67	Te-73	Au-100	I- 93	B-100	Ra-68	Te-53	Au-100	I-70
Cruise Ctrl on/off			58%					50%					47%					75%		
	B-75	Ra-53	Sm-37	Ba-87 Vz-60	Tx-93 A-38	B-60	Ra-50 F-50	D-50	Vz- 50. Ba- 88	Tx-88 A-50	B-71	Ra-43	Te-57	Ba-86 Vz- 71	Tx-86 V-50	B-87	Ra-60	D-40 Sm-40	Vz-80 Ba-87	Tx-100 V- 40
Cruise ctrl set			64%					50%					53%					85%		
	B-57	Ra-54	Sm-38	Ba-69 Vz-51	Tx-89 A-41	B-50	F-60	D-50	Ba- 70 Vz- 50	Tx-90 A-70	B-63	Ra-50	Sm-57	Ba-50 Vz-53	Tx-88 V-50	B-59	Ra-65	Sm-41	Ba-77	Tx-88 A-38 V-38
Cruise ctrl increase speed			65%					55%					53%					85%		
	R-58	Ra-61	D- 33 Sm-33 Te-33	Ba-69	Tx-61 A-44	R-45	Ra-64	D-36 Te-36	Ba-64 Ta-55	Tx-64 A-56	R-63	Ra-50	Sm-50 Te-50	Ba-63 Ta-63	Tx-59 A-33 V-33 G-33	R-65	Ra-65	D-47	Ba-77	Tx-59 A-42
Cruise ctrl decrease speed			65%					55%					53%					85%		
	R-61	Ra-61	Tx-36	Ba-69	Tx-61 A-44	R-45	Ra-64	D-37 Te-37	Ba-64 Ta-55	Tx-64 A-56	R-75	Ra-50	Te-50	Ba-63 Ta-63	Tx-63 A-33 V-33 G-33	R-65	Ra-65	Te-41	Ba-77	Tx-59 A-42

	All					Generation-Y					Engineer					Baby Boomer				
	Ctrl Type	**Elevation**	**Texture**	**Other**	**Label**	**Ctrl Type**	**Elevation**	**Texture**	**Other**	**Label**	**Ctrl Type**	**Elevation**	**Texture**	**Other**	**Label**	**Ctrl Type**	**Elevation**	**Texture**	**Other**	**Label**
Cruise ctrl resume			64%					50%					53%					85%		
	B-49	Ra-60	Sm-44	Ba-69 Au-60	Tx-89 A-39	B-40	Ra-60	Sm-50	Ba-70	Tx-90 A-60	B-50	Ra-50	Sm-71	Ba-50 Vz-50	Tx-100 V-38 G-38	B-53	Ra-65	D-47	Ba-77	Tx-82 V-40
Engine adjustments			24%					25%					40%					10%		
											B-33 O-33	Ra-83	Sm-50 Te-50	Ba-100 Ta-50 Vz-83						
Torque boost			42%					55%					40%					30%		
	B-70	Ra-71	Sm-71		Tx-73 V-38	B-64	Ra-64	Sm-73	Ba-80	Tx-73 V-60	B-83	Ra-83	Sm-67	Ba-67 Au-50 Vi-67 Ta-67 Vz-50	Tx-80 A-50					
Stereo on/off			33%					30%					20%					45%		
																B-78	Ra-67	Sm-44	Ba-89	Tx-56 V-60
Volume up/down			89%					100%					87%					80%		
	R-45	Ra-67	Sm-47	Ba-67	I-52	O-40	Ra-60	Sm-50	Ba-65	I-60	R-2	Ra-69	Sm-46 Te-46	Ba-85 Ta-54	I-62	R-50	Ra-75	Sm-44	Ba-56	Tx-67 V-60
Song rwd/fwd			40%					40%					47%					35%		
	R-46	Ra-46	Sm-64	Ba-68	I-55	B-38 R-38	Ra-50	Sm-50	Ba-75 Au-50	I-63	R-71	F-71	Sm-57	Ba-71 Ta-71	I-71					
Song next/prev			69%					85%					87%					40%		
	R-42	Ra-61	Sm-55	Ba-69	I-54	R-47	Ra-65	Sm-41	Ba-59 Ta-45	I-59	R-46	Ra-46 F-46	Sm-62	Ba-85 Ta-45	I-54	B-50	Ra-75	Sm-75	Ba-63	Tx-57 V-75

	All					Generation-Y					Engineer					Baby Boomer				
	Ctrl Type	Elevation	Texture	Other	Label	Ctrl Type	Elevation	Texture	Other	Label	Ctrl Type	Elevation	Texture	Other	Label	Ctrl Type	Elevation	Texture	Other	Label
Scan radio			38%					30%					33%					50%		
																R-40	Ra-78	Sm-67	Ba-56	I-56
Song play/pause			67%					65%					87%					55%		
	B-62	Ra-61	Sm-62	Ba-65	I-64	B-54	Ra-69	Sm-69	Ba-54 Vz-54	I-62	B-77	F-54	Sm-46	Ba-85	I-85	B-55	Ra-70	Sm-73	Ba-55	Tx-60 V-67
Song mute			64%					55%					73%					65%		
	B-69	Ra-57	Sm-37	Ba-74	I-56	B-82	Ra-46	D-36 Te-36	Ba-73 Ta-55	I-55	B-82	Ra-64	Sm-36 Te-36	Ba-82 Ta-55	I-73	B-46	Ra-62	Sm-46	Ba-69	Tx-58 V-57
Radio presets			38%					25%					33%					55%		
																R-55	Ra-82	D-55	Ba-64	Tx-64 V-50
Stereo mode			45%					50%					40%					45%		
	B-68	F-48	Sm-52	Ba-79	Tx-60 V-44	B-60	F-50	Sm-50	Ba-70 Ta-50	Tx-70 A-50	B-83	F-67	Sm-67	Ba-100 Au-67 Ta-58	Tx-50 V-60	B-67	Ra-56	D-44 Sm-44	Ba-78 Ta-60	Tx-56 V-40
Answer/hang up phone			69%					70%					80%					60%		
	B-76	Ra-55	Sm-45	Ba-84 Au-66 Ta-50	I-63	B-71	Ra-57	Sm-71	Ba-71 Au-57 Ta-50 Vz-57	I-63	B-83	F-50	Te-42	Ba-100 Au-67 Ta-58	I-75	B-75	R-67	D-42	Ba-83 Au-75	I-58
Browse contacts			35%					25%					47%					35%		
											B-57	Ra-57	Sm-57	Ba-86 Au-57	I-71					
Compose & send text message			35%					30%					33%					40%		
																B-100	Ra-75	D-50	B-100 Au-88 Ta-50	I-50

	All					Generation-Y					Engineer					Baby Boomer				
	Ctrl Type	**Elevation**	**Texture**	**Other**	**Label**	**Ctrl Type**	**Elevation**	**Texture**	**Other**	**Label**	**Ctrl Type**	**Elevation**	**Texture**	**Other**	**Label**	**Ctrl Type**	**Elevation**	**Texture**	**Other**	**Label**
Dial phone number			40%					25%					40%					55%		
	B-82 Voice-24	Ra-64	D-41	Ba-77 Au-77	I-68						B-100	Ra-50 F-50	D-50	Ba-100 Au-50 Vi-50 Vz-50	I-100	B-73	Ra-73	D-46	Ba-82 Au-91	I-55
Browse by artist/playlist/song/genre			31%					40%					20%					30%		
						B-50 O-50	Ra-75	Sm-50	Ba-75 Au-50 Vz-75	Tx-63 A-33 V-33 TR-33										
Navigation system functions			29%					15%					33%					40%		
																B-100	Ra-50	Sm-75	Ba-88 Au-88 Vz-50	Tx-75 A-33 V-33 TR-33
Walkie-talkie			36%					35%					40%					35%		
											B-100	Ra-33 F-33	Te-50	Ba-100 Au-50 Ta- 50	T&I-50 Ve-75					

*All numbers are percentages

**Abbreviations: B- button. R- rocker. O- other. Ra- raised. F- flush. Sm- smooth. D- dots. Te- texture. Ba- backlit. Au- auditory feedback. Ta- tactile feedback. Vz- visual feedback. Vi- vibration feedback. Tx- text. I- icon. V- verdana. A- arial. TR- times new roman. G- georgia

Overall, results in this study revealed that groups did have distinguishable differences in design preferences. While there were common themes, such as some controls like volume up and down being nearly universal between groups, these groups did also have measurable differences. Certain groups preferred some controls while others preferred to leave them off the steering wheel. When placed on the steering wheel, some groups preferred controls to be located in different places on the steering wheel.

Baby Boomers had a distinct disinterest in performance controls while Generation-Y were particularly fond of these controls. This is an area where marketing to these groups could become particularly frustrating if Baby Boomers were forced to use performance controls against their will, while Generation-Y may expect this level of control over their vehicle.

Cruise Controls were preferred, by all groups, on the steering wheel over the stalks, yet it is common to find production vehicles with cruise control functions on the stalks. If it is possible to integrate these controls onto the wheels it is recommended. All groups were interested in basic music controls on the wheel (i.e., volume up and down, song next previous, etc.). Baby Boomers wanted a variety of additional radio controls such as stereo on/off, scan radio, and radio presets.

Based on the voice control results, it is recommended that vehicles targeted at Baby Boomers integrate voice control for complex tasks. While this would also benefit other groups, Baby Boomers elected voice control more often than other groups. Also, Controls placed on the steering wheel that were more commonly selected for voice control were more complex tasks, indicating that users seem to understand the benefits of voice control and are willing to utilize it.

Generally, groups did tend to agree, with minor exceptions, on design details like control type and backlighting.

Perhaps the most revealing and impactful on future research were open-ended questions where participants were asked about their thought processes behind their design. Answers to questions like these can provide insight into the users' expectations, which cannot be revealed in letting users design. Understanding why users made their choices can also provide insight for future designs as well as current designs. When asked open-ended questions, engineers used a distinct vocabulary from other groups.

Conclusion

This study sought to understand what characteristics of a user-designed steering wheel might be common among three different participant groups, Generation-Y aged males and females, male engineers, and male and female baby boomers. The method in this study was largely exploratory but reflects a very modified version of a study by Green and Goldstein in 1989. Because no theory specifically applies to user design of steering wheels, users were given considerable freedom in their designs and asked a series of questions about their backgrounds and their designs in order to find variables common among the groups.

Anecdotal Participant Opinions

Positive Responses. Most, though not all, participants seemed capable of thinking through the options presented and creating feasible designs. Some participants welcomed the notion of creating innovative, unique designs which relied minimally on the status quo. In addition, many participants enthusiastically and voluntarily relayed stories, likes, dislikes and opinions about their own vehicles and borrowed or rented vehicles. Positively, most participants seemed to appreciate the opportunity to voice their opinions, expressing the need for car companies to consider what they want.

Negative Responses. Participants also expressed a few unexpected, negative behaviors during the study. Participants were required to locate all of the functions either on the steering wheel, center console or stalks. Some participants strongly opposed having to locate certain controls in one of these locations, to the point of nearly becoming angry. For example, some participants insisted the researcher make a note that while they had “chosen” to locate the window up and down function on the center stack, that they would not purchase a vehicle unless the window controls were located on the door. They adamantly did not want their opinions misrepresented in the data. Vehicle manufacturers might find it important to note that some users feel very strongly about where certain functions should be located, even to the extent that they may consider buying another vehicle based on where a single control is located.

Additionally, some participants (usually Baby Boomers) voiced strong opinions about features they believe to be distracting (i.e., compose and send text message and general internet functions). It should be noted that during the time of this study, “distracted driving” became a common phrase in news and media, as NHTSA, the CDC, AAA and others launched highly publicized campaigns to decrease distracted driving and to encourage drivers to be wise about cell phone use in vehicles (National Highway & Traffic Safety Administration, 2012; Distracted Driving, 2012; AAA Foundation for Traffic Safety, 2012). Many states and cities have made texting or using handheld phones illegal (Governors Highway Safety Association, 2013). The participants that were most concerned about these features seemed to believe that drivers should be given the option of being distracted by including these functions in the vehicle, even if those functions were voice controlled. A few participants seemed to accept these same functions only when they were voice controlled. Vehicles marketed at the Baby Boomer age group could consider eliminating features like texting or at least, make the feature easily integrated into voice controls to minimize perceived distraction by drivers.

Most participants completed the study in approximately two full hours. Some participants who picked designs with numerous functions became tired of the detailed questions towards the end of the experiment and sometimes seemed to select the first option or easiest option in order to simply finish the study. Future studies should consider shorter studies with fewer choices in order to maintain participant engagement.

Steering Wheel Structure

Among all groups, 10 participants designed steering wheels that were not round. While this deviation from a round steering wheel is becoming more common in high-end, luxury and sport vehicles, it is not a design feature on lower-priced, common vehicles. While several participants preferred this feature, interestingly, no participants in the study owned a vehicle with a non-round steering wheel. These participants preferred an option they, likely, had no extensive experience with. Most participants in all groups preferred three-spoke steering wheels (Generation-Y 60%, Engineer 60%, Baby Boomer 48%), but 20% Generation-Y and 40% engineers preferred four- spoke wheels. Interestingly, only 5% of Baby Boomers designed a wheel with four spokes. This could be because Baby Boomers were familiar with a four-spoke wheel, a somewhat common feature on vehicles in the 1980's and early 1990's. Because the Boomers had previous experience with these types of steering wheels, it is possible that they developed a preference for three-spoke (48%) and two-spoke (47%) wheels as opposed to four-spoke wheels. Generation-Y and young engineers would not necessarily have the same experience with these wheels, and therefore would not have developed a preference for three-spoke wheels over four-spoke wheels.

Baby Boomers also created designs with thicker spokes that were located lower on the steering wheel. Designs with lower and thicker spokes should be tested to see if they provide added comfort or safety.

Future designs should consider the growing interest in non-round steering wheels as well as interest in steering wheels with two or four spokes (particularly four-spokes for Baby Boomers). However, it is still true that all groups most commonly preferred a round, three-spoke design.

Number of Controls on the Steering Wheel

The number of controls on the steering wheel was not significantly influenced by age, gender, group, model year of current vehicle or technology affinity. This implies that there may be another unidentified variable that affects the number of controls a user wants to include on the steering wheel. The open-ended question responses indicated that participants based their steering wheel control decisions on what was most important to them, such as music, the act of driving itself or safety.

Location of Controls

Images of users' steering wheel designs were overlaid in translucent layers, creating a hot-spot-like effect for each group and all groups combined. A few trends were identified from this analysis. While most controls were placed on the upper two spokes, there were a many controls on the lower spokes. Placement of controls on the lower spokes is an uncommon design in present-day production steering wheels but may be a user friendly design option for designs, based on how frequently participants designed wheels with this arrangement. Overall, radio controls tended to be located on the upper spokes, most closely accessible by the thumbs. Engineers more strictly placed controls in this location than the other groups. Cruise control functions were also kept accessible on the upper two spokes. These are controls that users may have viewed as most critical and most frequently used and therefore, wanted to keep them easily within thumb reach.

Other functions such as phone and basic vehicle functions (i.e., window up and down, headlights on / off, etc.) tended to appear on the third, lower spoke. These functions that are placed on the lower third spoke may be considered less important than those placed on the top spokes yet are too significant to be relegated to the center stack. In future designs, to reduce clutter on the top two spokes, some less-used but still important functions like the phone and basic vehicle controls could be moved to the third, lower spoke.

More specifically, Generation-Y participants had the least amount of consistency in control placement. Radio, phone, cruise control and performance controls were placed nearly equally between the left and right side. Generation-Y also tended to select more performance controls than other groups. Engineers were very consistent in placing radio controls in a concentrated space on the top two spokes, and slightly favored the left side of the wheel. Phone and performance controls tended to be most concentrated on the right side. It is also of note that more than other groups, engineers tended to place controls on or very near the steering wheel grip, which would interfere with vehicle control. Baby Boomers placed radio controls on the left and bottom, phone controls on the bottom, cruise controls were most densely concentrated on the right, and basic vehicle controls were somewhat scattered. It is also of note that baby boomers selected more basic controls (which are not often included in current steering wheel designs) than other groups. Overall, radio controls were placed on the left, phone controls were most concentrated on the lower spoke and slightly less so on the right, cruise controls were to the right, as well as performance controls. Basic controls were scattered across the wheel with a slight tendency toward the left and bottom.

Participants were allowed to note which controls were located on the back of the steering wheel. However, only three participants elected this option. While controls located on the back of the steering wheel are available on several production vehicles, participants did not elect to use this location. Therefore, future steering wheel designs should consider keeping all controls on the front of the wheel.

Paddle shifters were surprisingly well received by participants in this study. Even though it was not tested equally with each group, an overall 53% preferred a paddle shifter to a standard, H-pattern gearshift. However, it should be of note that many participants did not have any experience with paddle shifters. Experience with paddle shifters or an H-pattern gearshift could alter the user's opinion. It is recommended that this option be studied further with equally sized groups, as well as users with and without experience with this type of transmission control.

Control Type

Buttons were the most preferred control type. Functions that were preferred to be buttons were strongly preferred (i.e., 65% or more of participants elected to use this control type). Rocker switches were the second most popular control. Rocker switches were commonly selected but less strongly than buttons (i.e., 58% or less chose this control type). Participants were generally good at selecting which controls would be appropriate for which functions. While other types of controls, like knobs and sliders, were less commonly selected, it should be noted that d-pad (based on video games such as Nintendo-64, and are currently seen on some production vehicles) and Apple iPod touch wheel-like controls were selected occasionally by participants and may facilitate ways to incorporate more functions on the steering wheel in a compact space.

It is also of note that some engineers would choose one button per control, leading to very crowded steering wheels. For example, an engineer used one button for up and another one for down. While this was an extreme participant, engineers did not tend to combine several functions into one control as often as other groups.

In current vehicle designs, many manufacturers integrate cruise control into the stalks. However, in this study, it was found that the majority of participants in all groups, preferred the cruise control to be located on the steering wheel in the form of buttons, even though placing these controls on stalks was an option.

Apple iPod Touch Wheel. Two Generation-Y participants included an unexpected design feature, the Apple iPod touch wheel. Participants were not allowed to include touch screens on the steering wheel because incorporating them into current vehicles could compromise safety standards. No participants specifically requested touch screens; however, a couple participants requested iPod touch wheels. Including a control similar to the touch wheel would allow many functions to be included in a compact space, as well as add a “cool” design feature to a steering wheel. With appropriate tactile and auditory feedback, a control similar to the iPod touch wheel may provide a viable option for integrating more controls onto a steering wheel. An iPod touch wheel could create a familiar and easy- to- use interaction (particularly when paired with auditory feedback), while also providing a “cool” and “unique” appeal. This concept should be tested further to determine its viability.

Control Design Characteristics

Most control designs were somewhat ubiquitous across functions. However, some design characteristics varied across groups. For example, 58% of Baby Boomers who selected the song mute function preferred it be labeled with text, while both Generation-Y and engineers preferred icons (55% and 73%, respectively). Design details such as backlighting and tactile feedback do not tend to vary by group, which means automotive engineers and designers may wish to focus efforts and resources on other details of the design.

As previously mentioned, participants in this study seemed hesitant to complete the control labeling selection of the study in order to avoid drawing. However, it is of note that Baby Boomers preferred text labels more often than Generation-Y or engineers. This could be (as some participants mentioned) because they had difficulty imagining an appropriate icon, which may also mean this age group has difficulty identifying unusual or uncommon icons. For these reasons, labeling should be re-examined in a future study.

Open- Ended Questions

In order to understand how participants were making design decisions, they responded to two open-ended questions: “What were your main considerations in creating your design and what was most important to you?” and “How did you decide what functions you wanted on the steering wheel?” While these were broad questions, they revealed some insights. Overall, when participants were asked their main considerations and what was most important, they responded strongly with “driving”, “use” (i.e., “what I use the most”), and “simplicity”. Other words like “convenience”, “hands” (i.e., “keep my hands on the wheel”), “ease”, and “buttons” (i.e., “The buttons should be close to my hands”) were also used. Such participant responses revealed an understanding and emphasis on appropriate concepts, like focusing on driving and keeping hands on the wheel by keeping buttons within reach.

The words commonly used by participants did vary somewhat among groups. Generation-Y had a strong focus on functions they use the most, with secondary considerations for keeping hands on the wheel, functions within reach, and an interest in cruise control. Baby Boomers focused on the primary task of driving, while desiring convenience and keeping controls within reach of their hands so that their hands could remain on the wheel. Engineers focused on slightly different concepts. Engineers were attentive to the controls themselves, such as the aesthetics, ergonomics and functionality, with an eye towards what is frequently used. While this appears to be a different focus than the focus of the other groups, it may not be. Engineers may have concentrated on these aspects in order to meet the needs they perceive the users to have. However, engineers should be sure to keep priorities in line with their users' expectations, wants, and needs.

When users were asked how they decided what functions to include, "use" (i.e., "what I use most often") was the most strongly preferred term. "Need," "driving" and "hands" were secondary terms that were closely followed by "often," "reach," "look" (i.e., "look away from the road"), and "safety". Again, responses show a tendency towards appropriate concepts like safety. In the responses to this question, all groups primarily utilized the term "use" to describe how they chose their functions. A closer look at the data reveals that this was almost always within phrases like "use most often", "use frequently", and "functions I use the most". Secondary terms for Generation-Y included "cruise control," "car" and "hand." Baby Boomers used different secondary terms. They mentioned "driving", " safety", "need", and "often" as well as "without", "eyes", "hands", "hunting", and "easy". Baby Boomers are clearly safety-focused, preferring to keep their eyes on the road and to avoid hunting for functions, thereby creating distractions. Again, the responses by the engineer group reveal a slightly different tone as compared to the other groups. "Driving" was a primary word, while "console", "features" and "frequency" were secondary. Less frequent words included "button", "paddles", "control", "functionality", "unique" and "good". As previously mentioned, this difference between engineers and the other groups can be bridged so long as engineers can keep their users' wants and needs a priority.

Like the Green, et al. (1987) Chrysler study, there was no single design favored by all participants. However, when breaking participants into age groups, it is possible to find trends within these groups and a design with commonalities among all groups. Overall, based on this study, people seem open to integrating certain unique ideas into the steering wheel, but automotive manufacturers should be cautious in their designs because even though many individuals were flexible while creating their design, some were very frustrated when having to place controls in locations that were not standard or familiar, or were intolerant of "unsafe" features (e.g. voice controls for Baby Boomers who feel talking on the phone in the vehicle should never happen). While generating new ideas is an appropriate process, ideas should always be tested with the correct user group before implementation in a final product. So long as designers and engineers can keep an eye towards innovation and a focus on the intended users' wants and needs, new and unique ideas can be successfully implemented so that vehicle design can keep pace with other advancing technologies.

The importance of input from the end user during the design process

It is also noteworthy that based on the engineer group in this study that automotive engineers in industry may underestimate users' desire to integrate unique and new functions on the steering wheel. The engineer participants included fewer navigation, climate control, and basic functions when compared to the other groups. Other groups may be willing to branch out and include other functions not commonly found on steering wheels, but that are also deemed important. It is also possible that engineers may select functions that other groups may not deem relevant to include on the steering wheel, such as the avatar function (a function that provides the car with a "personality" like a "wagging" antenna or an interactive cartoon-like character to assist with in- vehicle tasks like navigation). While this control was suggested by engineers as a possible function for the vehicle, it was rarely included on the steering wheel, and many participants were noted as not understanding what the function was or explicitly stating that this is not a function they would want on a vehicle at all. These differences illustrate the importance of engineers including customers outside of their engineering discipline in the design process.

Future Studies

This study provides a basis for a series of future studies in user-centered steering wheel design ranging from further investigation of preferences to methods for developing a prototype steering wheel. With the data provided in this study, it would also be possible and beneficial to compare the user's current steering wheel to the steering wheel they designed. This would help to understand how much users are willing to deviate from what they consider to be "normal" or "familiar." This information could help understand how to pace the unveiling of new features on vehicles. Additionally, more concrete and statistically based data could provide a platform for less subjective design process, one that would accurately quantify participant wants and needs, rather than be subjective to interpretation or artistic liberty.

Another future study should consider which functions should be incorporated in future designs. For example, if users want to include volume up and down in a design, engineer and designers can then also infer that mute and song next/previous should also be included in the design.

Conducting further qualitative research about user wants and needs, similar to that of the open-ended questions included in the current study, would help provide an understanding of the themes and considerations that are important to users. Understanding importance in a broad sense can help inform future designs without repeating past research for each iteration of steering wheels in the design process. Understanding the user’s thought process can also provide a level of detail to the design that is often missed in quantitative and specific research studies when aggregating data to create an average.

Future studies should create physical, working prototypes of the suggested prototype designs shown in the results section. Physical prototypes could be constructed by modifying current steering wheels and adapting them in a manner that accurately represents the three dimensional feel of the wheel, or by utilizing rapid prototyping techniques that are becoming more common. These prototypes should be used in a series of studies to determine the usability of the design. It is critical that participants should be allowed to interact with the physical prototype steering wheels in both static and dynamic environments. Dynamic environment tests can be conducted in a driving simulator so that testing unique steering wheel designs can be examined in a safe environment. Physical prototype testing in a simulator would also allow for studies that assess the interaction of steering wheel structure and where participants grip the wheel. The current study assesses user groups’ wants and needs in steering wheel functions and features, but future studies mentioned above would refine these wants/needs into precise prototypes that focus on users’ expectations and preferences.

APPENDICES

Appendix A

Participant Background Information

Participant # _______
Age:
Gender: M or F
Driving longer than 2 years? Y or N
Valid driver's license? Y or N
Student at CU-ICAR? Y or N
Familiar with CU-ICAR's Deep Orange 1 vehicle? Y or N
What car do you currently drive (or drive the most)?
Make_____________ Model________________ Year_________________

Without new technologies society can no longer function.

1	2	3	4	5
Strongly Disagree				Strongly Agree

Often it is easier to do things without using technologies.

1	2	3	4	5
Strongly Disagree				Strongly Agree

I do not use technologies, because they fail when you need them the most.

1	2	3	4	5
Strongly Disagree				Strongly Agree

I get nervous using technology because I might break something

1	2	3	4	5
Strongly Disagree				Strongly Agree

How often do you use the internet?

a. Several times a day
b. About once a day
c. A few times a week
d. Every few weeks
e. Never

How often do you use a cell phone?

a. Several times a day
b. About once a day
c. A few times a week
d. Every few weeks
e. Never

Appendix B.

Participant responses to technology affinity questions

Scaled Technology affinity questions

	All			Gen-Y			Engr			BB		
	M	SD	Range	M	SD	Range	M	SD	Range	M	SD	Range
Without new technologies society can no longer function. 1 = strongly disagree. 5= strongly agree	3.2	1.2	1 - 5	3.4	1.0	1 - 5	3.1	1.4	1 - 5	3.0	1.4	1 - 5
Often it is easier to do things without using technologies. 1 = strongly disagree. 5= strongly agree	2.9	1.1	1 - 5	2.4	0.7	1 - 4	3.5	1.2	2 - 5	3.1	1.2	1 - 5
I do not use technologies, because they fail when you need them the most. 1 = strongly disagree. 5= strongly agree	1.8	0.9	1 - 4	1.5	0.6	1 - 3	2.2	1.1	1 - 4	1.8	1.1	1 - 4
I get nervous using technology because I might break something. 1 = strongly disagree. 5= strongly agree	1.5	1.0	1 - 5	1.7	1.2	1- 4	1.3	0.8	1 - 4	1.6	0.8	1 - 4

Multiple choice technology affinity questions.

		All	Gen-Y	Eng	BB
How often do you use the internet?	Several Times a Day	94.5	100.0	100.0	85.0
	About Once a Day	1.8	0.0	0.0	5.0
	A few times a week	0.0	0.0	0.0	0.0
	Never	1.8	0.0	0.0	5.0
How often do you use a cell phone?	Several Times a Day	92.7	100.0	100.0	80.0
	About Once a Day	3.6	0.0	0.0	10.0
	A few times a week	0.0	0.0	0.0	0.0
	Never	1.8	0.0	0.0	5.0

<u>Appendix C</u>

<u>Twelve Example steering wheels</u>

2011 Citroen C5.

2010 Audi R15

2009 BMW F1

2006 Spyker 8C

2010 Ferrari 458

2007 Toyota Camry

1966 Chevrolet Corvette

2010 Lotus Elise Concept Car

2011 Volkswagen concept car

2008 7 series BMW

2010 Range Rover.

2011 Porsche Cayman S.

Appendix D

Vehicle Functions

List of possible functions:

1. Seat adjustments
2. Climate ctrl temperature
3. Climate ctrl fan speed
4. Climate Ctrl fan location/mode
5. Driver window up/down
6. Passenger window up/down
7. Seat climate Ctrl
8. Sunroof ctrl
9. Engine on/off
10. Horn
11. Cruise ctrl on/off
12. Cruise ctrl set
13. Cruise ctrl increase speed
14. Cruise ctrl decrease speed
15. Cruise ctrl resume
16. Headlights auto/on/off
17. High beams on/off
18. Blinkers/indicators
19. Hazard lights
20. Dome light auto/on/off
21. Fog lamps on/off
22. Windshield wipers auto/on/off
23. Windshield wipers speed/inter.
24. Windshield wiper fluid/clean
25. Windshield defrost
26. Rear window defrost
27. Door lock/unlock
28. Suspension adjustments
29. Engine adjustments
30. Left & right mirror adjust
31. Traction ctrl on/off
32. Trunk pop
33. Hood pop
34. Garage door/gate open/close
35. Torque boost
36. Stereo on/off
37. Volume up/down
38. Song rwd/fwd
39. Song next/prev
40. Song repeat/shuffle
41. Scan radio
42. Song play/pause
43. Song mute
44. Radio presets
45. Equalizer adjustments
46. Stereo mode
47. Answer/hang up phone
48. Browse contacts
49. Compose & send text message
50. Dial phone number
51. Send location to others
52. Cell phone holder/charging port
53. "Favorite"/"like" song
54. Playlist generation
55. Browse by artist/playlist/song/genre
56. Internet functions
57. Navigation system functions
58. Traffic updates
59. Download media content
60. Dashboard configuration
61. Vehicle configuration
62. Avatar action button
63. Avatar on/off
64. Store media content
65. Walkie-talkie

Appendix E

Control Information

Number: ______

What does this control do? ____
(Optional description of function):

Type of control (Select only one):

- ☐ Touchscreen
- ☐ Button
- ☐ Knob
- ☐ Thumb wheel
- ☐ Rocker switch
- ☐ Switch
- ☐ Other: ____

Control characteristics (Select when applicable):

Elevation: Raised / Flush / Sunk

Texture: Dots / smooth / textured

Other: ____

Design Characteristics (Select all that apply):

- ☐ Backlit
- ☐ Programmable
- ☐ Removable/Battle Ship
- ☐ Auditory feedback
- ☐ Vibration feedback
- ☐ Depression feedback
- ☐ Visual feedback
- ☐ Other: ____
- ☐ Other: ____
- ☐ Other: ____

Do you want **Text / Icon / Both text and icon** for this control? (Circle One)

	Select a text:	**Draw your Icon:**
1	**Arial –** AaBbCcDdEeFeGgHhIiJjKkLlMm NnOoPpQqRrSsTtUuVvWwXxYyZz	
2	**Verdana-** AaBbCcDdEeFeGgHhIiJjKkLlMm NnOoPpQqRrSsTtUuVvWwXxYyZz	
3	**Times New Roman-** AaBbCcDdEeFeGgHhIiJjKkLlMm NnOoPpQqRrSsTtUuVvWwXxYyZz	
4	**Georgia-** AaBbCcDdEeFeGgHhIiJjKkLlMm NnOoPpQqRrSsTtUuVvWwXxYyZz	

Appendix F

Study Script

Intro/Background
Thank you for participating in this study.
First, I would like to ask you a few of background questions.
(See **Error! Reference source not found.**)

Show Deep Orange Video
In order to provide some context for the tasks in this study, I'm going to show you a brief video about CU-ICAR, the Deep Orange project and the Deep Orange 1 car.

PLAY VIDEO (http://www.youtube.com/user/ClemsonUniversity#p/c/6/3sh3ooZNhCc)

As discussed in the video, one goal of Deep Orange is the integration of technology into the vehicle. This study is being conducted with that goal in mind. So for this study, I'm going to ask you to design your ideal steering wheel for this car, a small, hatchback, electric sports car. In a minute, I'll explain exactly how we are doing that.

Do you have any questions?

Summary of Study
This study seeks to understand the user's wants and needs in a radical new steering wheel design developed for the Deep Orange 1 car. For the duration of the study, I encourage that you think outside the box. Imagine that anything is possible and disregard things that may seem "impossible" due to cost, current technologies or current designs.

You will notice that on the wall there are images of various, unique steering wheels to provide some inspiration, but feel free to incorporate any ideas you think of, even if they are not seen here.

Remember that your design would be used in a small, electric sports car (i.e., The Deep Orange 1 car).

Study Procedure
I am providing you with a square piece of cardboard. This is the size of the wheel designed for the Deep Orange 1 vehicle, and you will use it as a base. Marked on it are two circles to indicate the grip of the steering wheel.

First, I would like you to choose the steering wheel spokes. You may choose as many or as few as you like. I have provided some pre-cut shapes, but if you would like to create your own, you are welcome to do so using this red paper.

I would also like you to pick out the center "hub" of the steering wheel (the part where the airbag and horn are typically found). Again, I have provided some pre-cut shapes and sizes that you may use, but if you would like to create your own, you may do so using the red paper. Feel free to try several options before settling on one design. And at any point in this study, you are welcome to go back and change your design.

PROVIDE TIME TO CHOOSE OPTIONS HERE

Next, I would like for you to think about the features you would like to have on the steering wheel. Please use the names of items on this table to help you think of features you would like to have on a steering wheel. Remember, these are supposed to help you brain storm ideas but not limit them, so if a feature you want is not listed, feel free to let me know. You may choose as many or as few as you would like. Feel free to make changes as you go along and develop your ideas.

PROVIDE TIME TO CHOOSE OPTIONS HERE

Now that you have a good idea of what features you would like, I am going to move your design over here and we are going to trade places.

MOVE THEM. SWAP SEATS.

Now, I would like you to think about replacing these words with buttons, knobs, or a different type of control. You are going to choose what controls you would like to have for the features you selected. The controls are represented by these shapes. You can decide whether these shapes are buttons, knobs, touch screens, scroll wheels, or any other type of control you can think of. If the shape and size you would want are not provided, use the red paper to cut your desired shape and size. The controls are in these envelopes, grouped by category. So if you want a radio control, like volume, please take a shape from in front of this group. They are color coded by category for the purpose of my data analysis. The controls would not actually be these colors in your design; they are simply for my data analysis. If you are unsure what category the control you want is, feel free to ask me. As you pick up each colored shape, write the number of the feature on that shape. For example, the horn is number 21, and I want the button to go here. So I would place the colored shape here and number it 21.

GIVE TIME

Once you feel comfortable with your design, please glue all the pieces where you want them.

Now, I will give you a form that I want you to read along with, as I fill out an identical form for you. For each one of your features, I now know the size and shape you want, but I don’t know how you want it to work. So I want you to look at this list of controls and tell me what you have in mind. For example, I want a horn that is a button that I push with my thumb, so I would say “Button”. Next, I would then say I want it raised from the surface, and have a texture to it, as well as that I want to be able to hear it, so I want it to have auditory feedback.

GO THROUGH WHOLE SHEET FOR EACH FEATURE

Now, I would like to ask you a short series of questions about your design decisions.

Thank you for your participation!

Appendix G

Post Design Questions

What were your main considerations in creating your design? What was most important to you?

I considered aesthetics when creating my design.

1	2	3	4	5
Strongly Disagree				Strongly Agree

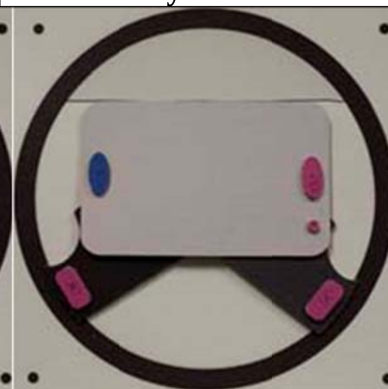
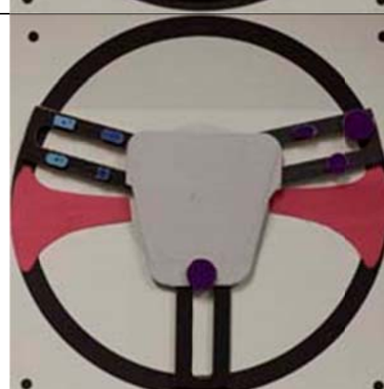
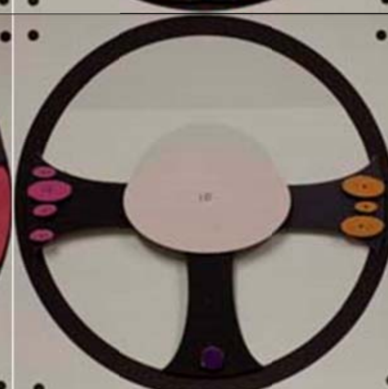
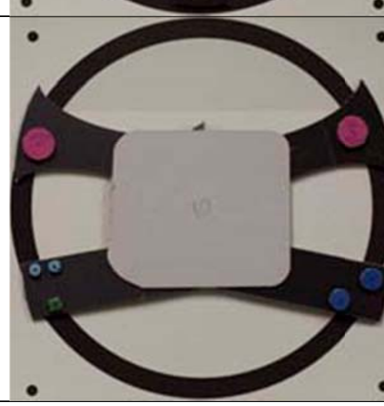
I considered functionality when creating my design.

1	2	3	4	5
Strongly Disagree				Strongly Agree

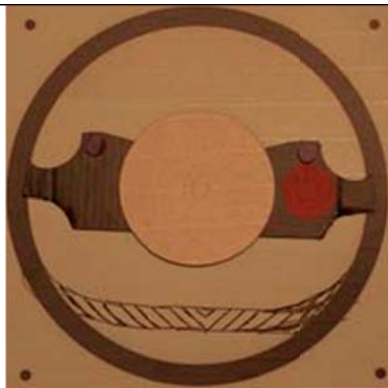
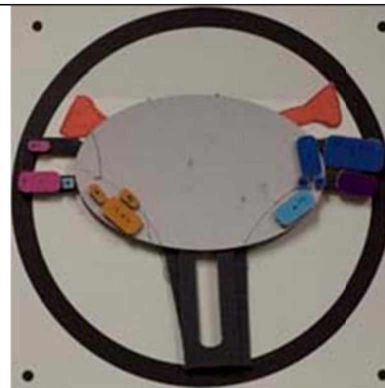
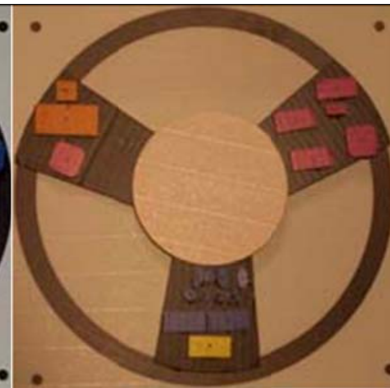
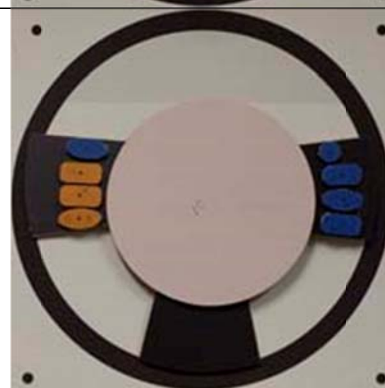
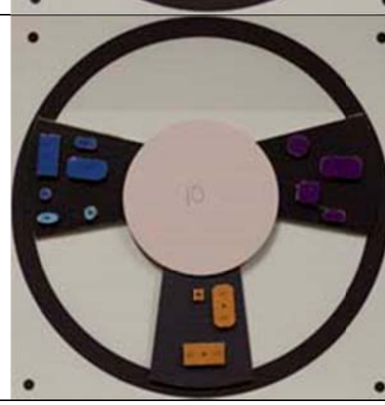
How did you choose what features you wanted on the wheel?

Appendix H

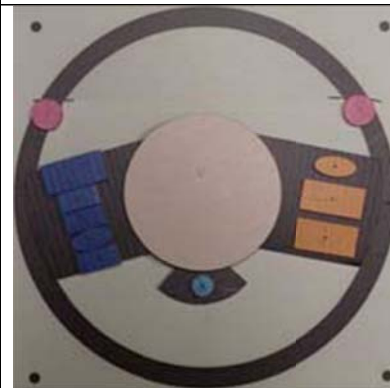
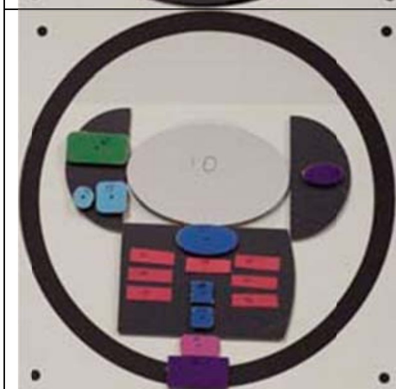
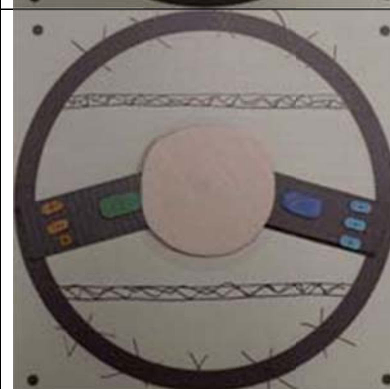
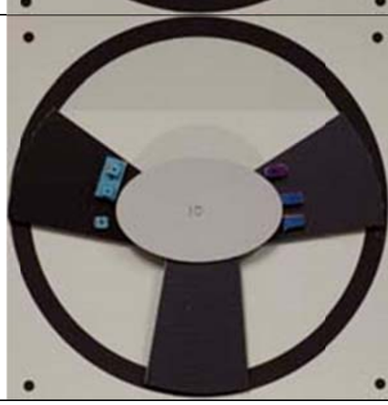
Images of participant steering wheels

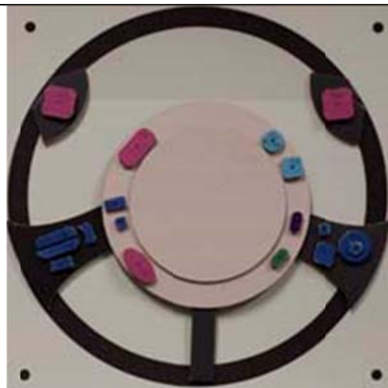
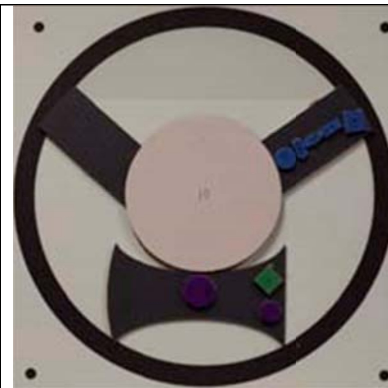
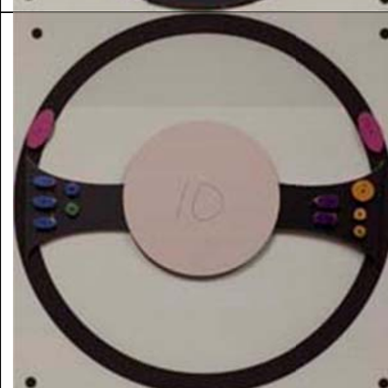
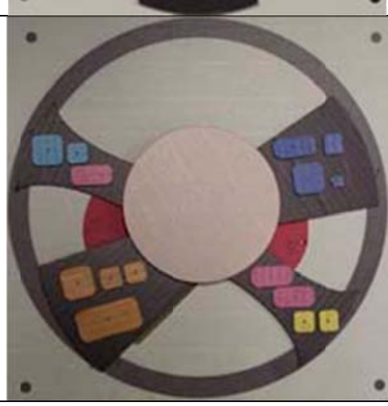
	Generation- Y	Engineer	Baby Boomer
MALES			
			
			
			

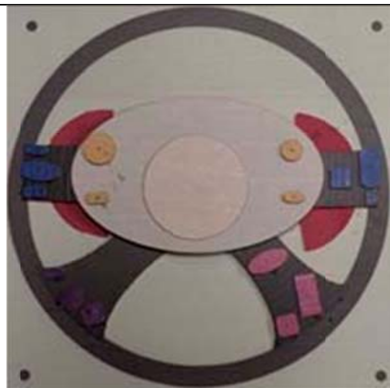
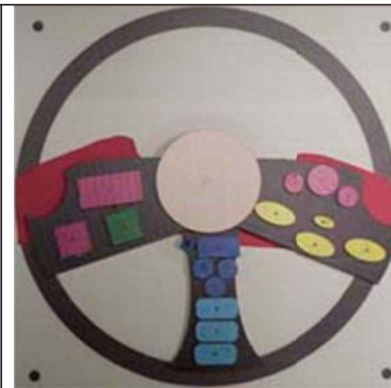
MALES

MALES			
			
			
			

MALES			
			
			

	Generation-Y	Engineer	Baby Boomer
FEMALES			
			
			
			

FEMALES			
			
			
			

FEMALES			
			

Appendix I

Wordle word frequencies for open-ended questions.

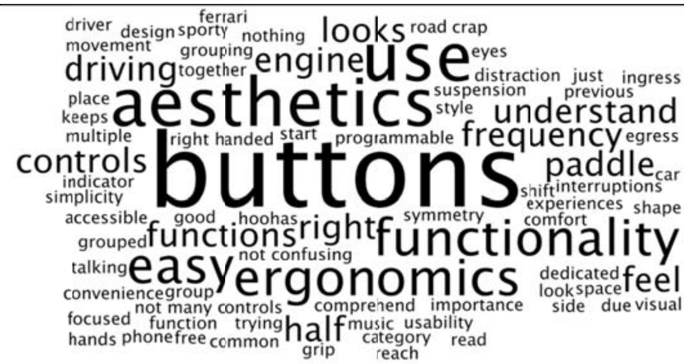
Steps for www.Wordle.net analysis:

A. Prep in Word
   1. Copy all into word doc.
      a. Blank line between participants.
      b. Keep in number order.
   2. Make all conjunctions 2 words. Ex. don't → do not
   3. Delete:
      a. Like
      b. Important
      c. Want (?)
      d. Wanted
      e. Things
      f. Steering Wheel (but not "steering"!)
      g. Wheel
      h. Too
      i. Put
      j. stuff
   4. Things like "right handed" → "right~handed"
      a. Right handed
      b. Left handed
   5. *Anything with "not" needs to be hyphenated "not cluttered" → not~cluttered*
   6. "Not cluttered" → uncluttered
   7. "cruise control" → cruise~control

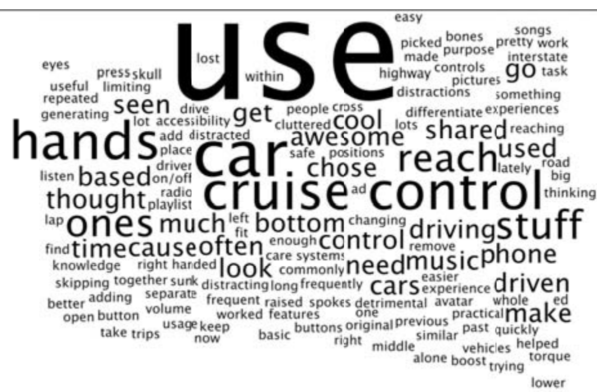
B. Steps in Wordle
   1. Set to black and white in wordle
   2. Make all words lower case
   3. Font: lucida sans
   4. Straighter edges
   5. Horizontal
   6. Copy and paste word count into corresponding document

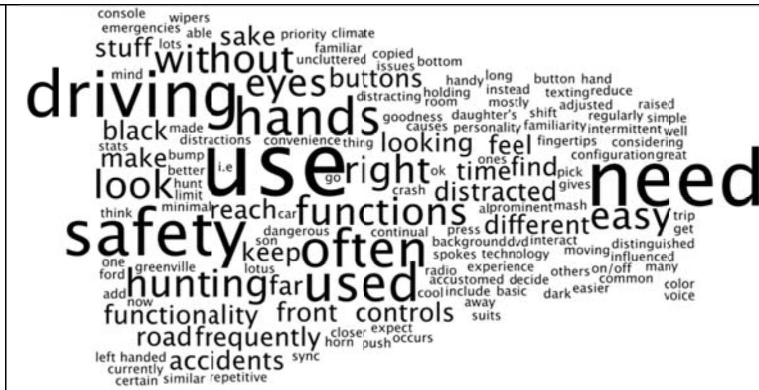
Question1*: What were your main considerations in creating your design and what as most important to you?*

All Groups		1. Use- 14 2. Buttons- 12 3. Driving- 11 4. Hands- 8 5. Functions- 8 6. Simplicity- 8 7. Convenience- 7 8. Easy- 6 9. Look- 6 10. Right- 5
Generation-Y		1. Use- 5 2. Simplicity- 4 3. Music- 4 4. Functions- 3 5. Uncluttered- 2 6. Right- 2 7. Look- 2 8. Buttons- 2 9. Driving- 2 10. Used- 2
Baby-Boomer		1. Driving- 6 2. Hands- 5 3. Convenience- 5 4. Use- 5 5. Ease- 4 6. Buttons- 4 7. Safety- 3 8. Look- 3 9. Grip- 3 10. Hand- 3

Engineer		1. Buttons- 6 2. Use-4 3. Aesthetics- 4 4. Easy- 3 5. Ergonomics- 3 6. Understand- 2 7. Frequency- 2 8. Driving- 2 9. Half- 2 10. Paddle- 2

***Question 2**: How did you decide what functions you wanted on the steering wheel?*

All Groups		1. Use- 28 2. Driving- 13 3. Hands- 9 4. Car- 7 5. Used- 7 6. Look- 6 7. Right- 5 8. Buttons- 5 9. Reach- 5 10. Safety- 5
Generation -Y		1. Use- 11 2. Car- 5 3. Cruise Control- 4 4. Hands- 4 5. Ones- 3 6. Stuff- 3 7. Reach- 3 8. Need- 2 9. Time- 2 10. Awesome- 2

<table>
<tr><td>Baby-Boomer</td><td>
</td><td>1. Use- 7
2. Need- 6
3. Driving- 5
4. Safety- 5
5. Often- 4
6. Hands- 4
7. Used- 4
8. Eyes- 3
9. Right- 3
10. Functions- 3</td></tr>
<tr><td>Engineer</td><td>
</td><td>1. Use- 10
2. Driving- 6
3. Features- 3
4. Console- 3
5. Frequency- 3
6. Center- 2
7. Button- 2
8. Buttons-2
9. Unique- 2
10. Paddles- 2</td></tr>
</table>

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