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Cross-generational acceptance of and interest in advanced vehicle technologies: A nationwide survey

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ABSTRACT

The number of older drivers on the roadways is increasing; at the same time, technology in the automotive environment is rapidly evolving. To investigate the potential impact of these converging changes, this study used a cross-generational approach to compare driver attitudes toward advanced automotive technologies. Approximately 1000 drivers between the ages of 18 and 85 located across the United States responded to a survey about their opinions regarding general technology, advanced in-vehicle technology, and near-horizon connected vehicle systems. Participant responses were categorized using a generational construct, sorting responses not only by age but by shared life experiences (e.g. economic circumstances, involvement in wartime activities, cultural movements, etc.). The oldest generation (the "Silent" generation) exhibited the least interest in and comfort with advanced technology, although they owned and used advanced in-vehicle technology at approximately the same rates as the two middle generations. The youngest generation (the "Millennial" generation) was most likely to be interested in and comfortable with technology, but was least likely to own vehicles with advanced technology. All participants expressed interest in safety-related connected vehicle systems, but less so in infotainment applications. Reservations regarding data security and system cost were shared across generations. These findings are framed in the context of an aging population with unique driving and vehicle needs, and provide information that may assist both with vehicle technology design aspects and the proposed large-scale implementation of connected vehicle systems, including considerations for seniors and emphasis on safety systems and data security.

1. Introduction

The landscape of vehicle-related technology is in a state of rapid change, brought about by advances in wireless connectivity, rapidly increasing integrated computing power, and the ubiquity of advanced mobile devices such as smartphones, music players, and navigation systems. Vehicle technology advances are being developed and integrated from multiple directions. Vehicle and device manufacturers are competing to provide drivers with the newest technological options, while the government has recently begun moving forward to incorporate advanced wireless communication technology to allow vehicles to

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communicate with each other and with infrastructure using "connected vehicle" systems (CVS). These changes are enabling new opportunities to advance driver safety, in-vehicle entertainment, vehicle control, and how drivers interact with the roadways and the surrounding environment. However, these advances also have the potential to add complexity and variability to the driving experience, which may disproportionately affect those who are least able or willing to deal with such changes. Older drivers, who often are already facing a variety of physical, perceptual, cognitive, and social challenges typically associated with aging, may find interacting with these novel technologies particularly daunting, particularly if they increase the cognitive load of the driver beyond what he or she is comfortable with. In addition, the current generation of older drivers is one of the last generations to have come of age before microcomputers became ubiquitous, and these individuals may be less familiar with and accepting of the general computing technology that underlies vehicle system interfaces.

Because of this convergence of increased vehicle technology, the impending arrival of CVS, and an aging driving population (National Safety Council, 2008), it is of critical importance to consider the impact of advanced vehicle technology on current older generations relative to younger generations, and the potential adoption of these systems by younger generations as they age. The population of the United States is aging rapidly, and is expected to continue to do so for the next several decades. In 2013, there were more than 7.3 million licensed drivers age 65 and older in the United States (Federal Highway Administration, 2015), and Census projections predict that those aged 65 and older will increase their percent of the total population by over 40% over the next 20 years, in direct contrast to all other age groups, which show flat or slightly decreasing projected percentages over that same timeframe (U.S. Census Bureau, 2012). While several studies have been conducted or are underway on general interest in and acceptance of advanced vehicle systems (Schoettle & Sivak, 2014) and the design characteristics of these systems (Brugeman, Wallace, & Cregger, 2012; Intelligent Transportation Systems Joint Program Office, 2013a), investigations that consider the effects of driver age and generational association on driver interest in and acceptance of advanced vehicle technology are needed.

1.1. Current in-vehicle technology

Recent advancements in technology have had far-reaching implications for vehicle design and the availability of novel features. In-vehicle information and entertainment (*infotainment*) options, for example, had remained relatively constant for several decades, and were generally limited to an AM/FM radio and a physical media player controlled by a small number of buttons and/or knobs. Within the past several years, however, the complexity and variety of infotainment options in vehicles has undergone a revolution corresponding to the rapid rise of mobile computing and connectivity. Today, many vehicles include a touchscreen system that allows the driver to interact with a variety of infotainment options, including terrestrial, satellite, and internet radio, compact discs, portable music players, and smartphones via auxiliary input, Bluetooth, and/or USB audio streaming. In addition to entertainment, these systems often also offer climate controls, internet connections, navigation and destination features, as well as access to advanced vehicle settings, functions and diagnostics. Automotive infotainment interfaces are rapidly changing from traditional vehicle-based controls into interfaces similar to modern computers and tablets.

In addition to advanced infotainment technology, new types of technology are designed to help the driver avoid crashes. These crash-avoidance technologies include systems such as backup cameras that supplement rear-view mirrors (with interfaces often contained in the same screen used for infotainment purposes), collision warning systems that alert drivers to impending conflicts using radar or machine vision, adaptive cruise control that can maintain a constant distance to a vehicle ahead, and night vision systems that can allow drivers to better detect pedestrians or animals in the roadway, among others. Like the advanced infotainment technology discussed above, most of these crash avoidance technologies have been introduced only in the past half-decade or so and are increasingly available across newer vehicle platforms.

1.2. Connected vehicle systems

The National Highway Traffic Safety Administration recently announced that it will begin the process of considering a mandate for CVS including vehicle-to-vehicle (V2V) technology for light vehicles in the United States (National Highway Traffic Safety Administration, 2014). In September 2014, General Motors announced that at least one 2017 Cadillac model will be one of the first production vehicles to incorporate V2V technology (Media.Cadillac.com, 2014) This combination of regulatory and commercial milestones sets the foundation for continued development and implementation of V2V technology, which allows vehicles to communicate with other similarly equipped vehicles in close proximity using Dedicated Short Range Communication (DSRC), a variant of Wi-Fi (Intelligent Transportation Systems Joint Program Office, 2013b). V2V communications convey pertinent location, speed, direction, and other vehicle data, and can be utilized in a variety of ways to improve safety and otherwise improve the driver's roadway experience. A typical implementation is to allow equipped vehicles to "know" where similarly-equipped nearby vehicles are located and headed. For example, if a driver attempts to pass a lead vehicle on a winding road, a CVS V2V system could alert him or her to an oncoming vehicle that is predicted to pose a conflict (Fig. 1A). If a vehicle is approaching an intersection, CVS could alert it to a rapidly approaching vehicle with which the driver is predicted to collide (Fig. 1B).

Further extension of CVS technology includes vehicle-to-infrastructure (V2I) communication, which enables vehicles to rapidly exchange information with infrastructure features such as intersections, allowing smart intelligent traffic signal control, dynamic routing (e.g. to avoid traffic), and highly-localized weather/roadway information systems among many

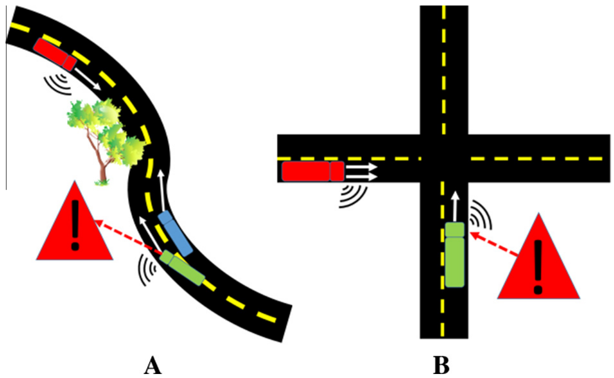

Fig. 1. Example scenarios where a CV system could issue a collision warning.

other applications. The possibility of ubiquitous cellular connectivity also enables applications that are focused on enriching the driving experience rather than specifically intended to improve safety and/or mobility. Some newer vehicles are already offering such applications in the areas of social media and internet connectivity (for example, the Ford Sync AppLink allows voice control of Twitter and internet radio applications); in addition, much like the internet, vehicle connectivity is expected to result in a proliferation of many new applications.

While appropriately implemented CVS technology has far-reaching implications for improving traffic safety, it is an open question how readily it will be accepted across the driving generations, particularly older generations. Factors in acceptance may include both expressed interest in and actual experience with current technology, appeal of the connected features being offered, and concerns over the usability and security aspects of CVS.

1.3. Older drivers and advanced technology

The rapid pace of technological advancement and the rise of the internet and mobile computing may present a unique set of challenges to current older drivers, who already experience perceptual, physical and cognitive challenges related to aging that can make the driving task more difficult (Dobbs, 2008; Salthouse, 2000; Wood, 2002). Such aging-related challenges may be related to the higher at-fault crash involvement ratio that older drivers exhibit compared to younger drivers (Stutts, Martell, & Staplin, 2009), and the relation between these technological and personal challenges and older drivers' acceptance of advanced technologies is not yet well understood. Potentially compounding these physiological factors, current older drivers are members of a generation that came of age well before the computer revolution, which suggests that they may be less willing to engage with technologies with which they have less experience.

Individuals from older generations are often slower to adopt new technology, and may not feel as comfortable with it as younger generations do (Czaja et al., 2006). According to a recent survey, 53% of those 65 and older used the internet, but only 34% of those 75 and older did so. This compares with 77% of adults ages 50–64 and 97% of adults ages 18–29 (Zickuhr & Madden, 2012). In addition, only 69% of seniors over age 65, and 57% of seniors over age 75, owned cell phones, compared to 87–95% of respondents in younger age groups. More recently, Rainie and Smith (2013) found that only 18% of seniors over age 65 owned a smartphone, compared to 45–79% of younger generations, and 18% of seniors owned tablet computers, compared to 31–44% for younger generations. These findings suggest that, while members of older generations may not be entirely averse to using advanced technology, they adopt it at much lower rates than even their middle-aged counterparts.

Charness and Boot (2009) note a variety of factors that may make it more difficult for seniors to engage with technology, including attitudinal, cognitive, and motoric factors, and note that much of this difficulty is due to interface design that does not take these factors into account. Cognitive impairment in seniors has also been associated with perceived difficulty of use of relatively simple technology such as remote controls and microwaves (Rosenberg, Kottorp, Winblad, & Nygard, 2009). However, individual and group training on computer and internet use for seniors has shown success in improving comfort with computers and improvements in ratings of social support and connectivity (Cody, Dunn, Hoppin, & Wendt, 1999) and well-being, sense of empowerment, and cognitive function (Shapira, Baraka, & Gal, 2007). Further, there is some evidence that substantial numbers of seniors use the internet for medical information, for both specific questions (Flynn, Smith, & Freese, 2006) and general insight into aging and the maintenance of independence (Harrod, 2011). These studies suggest that it may not be simply the aging process *per se* that inhibits older adult engagement with technology, and that proper design and training may enable current older generations to engage with advanced technology in constructive ways; further, it suggests that future generations of seniors, including today's younger and middle-aged drivers, may have less difficulty adapting to advanced technology in their vehicles, since they are more likely to be accustomed to interacting with computer-enabled electronic devices across their lifespan. On the other hand, the ever-increasing pace of technological innovation makes it difficult to predict how future generations of seniors may engage with the currently unimagined technological innovations to come.

1.4. Using generational constructs to examine driver attitudes

The generational construct provides a refined context for evaluating emerging technology and how readily or ultimately the degree to which individuals of different generations might accept or adopt such a technology. Demographers have long classified individuals into particular "generations" or "cohorts" based on large-scale population trends (e.g., the "baby boom"), era-defining events (e.g., world war or global depression), or other sociological, economic, or technological trends (Carlson, 2009; Ryder, 1965). The core idea of the generational construct is that membership is not merely a fact of birth; instead, it is seen as an important and lifelong shaper of one's values, attitudes, and, ultimately, how one perceives and responds to one's environment. One could evaluate the acceptance of new technology through the prism of age alone, but that approach presupposes, in essence, that each successive generation will share similar values and life experiences.

This study includes the five primary living generations of driving age in the United States, defined as the Millennials (born 1983–2001; current age 18–31), Generation X (b. 1965–1982; age 32–49), the Baby Boomers (b. 1946–1964; age 50–68), and the Silent Generation (b. 1929–1945; age 69–85), after Carlson (2009). An attempt was made to incorporate the Greatest Generation (b. 1909–1928), but too few responses were obtained for statistical significance.

As technology has undergone a revolution over the past several decades, the newly-licensed drivers of today have grown up in a vastly different technological environment from their parents and grandparents, both in general and in the driving context. The first personal computers (PCs) became available for consumer purchase during the early 1980s, as the Baby Boomers reached adulthood, and the latter part of Generation X became the first generation to grow up with regular access to home computers. Similarly, as mobile phones and GPS systems became popular in the 1990s, Generation X was the first to come of driving age with these available as a component of the driving experience. Millennials, meanwhile, were the first generation to grow up with the internet being regularly available in the 1990s, and the rapid advance of computing power around the turn of the 21st century enabled the transformation of mobile phones in the mid-2000s from single-function devices into pocket-size computers that allow voice and video calling, text messaging, email, GPS navigation, social media (itself a new invention) and much more. In addition, mobile phone interfaces underwent a drastic transformation from physical buttons – often simply a 0–9 keypad with a few auxiliary buttons, although QWERTY keyboards were popular for several years – into the smartphone touchscreens that currently dominate the market. As of December 2013, over half of all wireless connections were smartphones (CTIA – The Wireless Association, 2014). Due to these dramatic changes, current and future generations entering driving age may be much more familiar with and accepting of general technology and in-vehicle technology, including advanced vehicle safety systems, than previous generations.

Advanced in-vehicle technologies that are currently or soon to be on the market combine a rich and evolving set of options and opportunities which can lead to complex user interfaces that may prove challenging for some drivers who lack general familiarity with advanced technology (Wagner, Hassanein, & Head, 2010). As the world's population continues to age, a fundamental question has emerged as to whether or not these new technologies will be understood, accepted, and used by the senior drivers of today and tomorrow in such a way that safety is ultimately enhanced. The goal of the current study was to conduct a nationwide survey to compare driver attitudes across the main driving generations in terms of interest in general technology, usage of vehicle-specific advanced technology, and interest in advanced CVS technology.

2. Method

2.1. Survey development

Researchers at the Virginia Tech Transportation Institute (VTTI) with expertise in connected vehicle technology and older driver research, in consultation with the Virginia Tech Center for Survey Research (CSR), developed a telephone survey to assess the attitudes of drivers toward general technology, in-vehicle technology, and CVS. The final questionnaire included 63 questions covering a range of opinions about and experience with general and vehicle-specific technology, opinions about existing and potential CVS features and concerns, and participant demographics; the results presented here represent a subset of these questions that were selected for general interest. The final survey topics were determined by the research team in conjunction with the sponsor, the National Highway Traffic Safety Administration, based on a balance of breadth of inquiry and survey brevity, and the specific survey items were developed using VT CSR principles in order to adhere to best practice standards in obtaining optimal response rates while minimizing bias in response. The survey instrument was pretested using live interviewers and a computer assisted telephone interviewing (CATI) system in an iterative process in which a small number ($N = 20$ cases) of interviews were completed with a sub-group of pre-respondents that would have been otherwise eligible for selection for the sample for the primary survey. Interviewers for the pre-test completed standard interviews with follow up debriefing among the interviewers and standard behavior coding protocols, making suggestions for improvement of the survey instrument based on respondent input.

One consideration when developing this survey was the interplay between providing respondents with sufficient information to express educated opinions about unfamiliar CVS technology without overwhelming them with complex information. It was determined that participants would first be asked about their level of interest in specific benefits that CVS could provide, followed by asking their levels of concern regarding various aspects of such a system design. This paper presents a subset of results collected from this larger survey; the full survey results are reported in Owens and Antin (2014).

2.2. Survey delivery

CSR conducted this survey on a representative sample of adult drivers in all 50 states representing the five main driving generations. A random-digit dialing (RDD) method was employed by the CSR for administration of the survey. Both listed and unlisted as well as cellular telephone numbers were included in the sample for this project. Pre-targeting based on predicted age within the household was employed by age only in the case of the hardest to reach populations (based on numerous general population telephone surveys conducted by the CSR). Specifically, approximately 20% of the numbers included in the sample pool for the study were targeted and randomly selected to include a household member in the 18–25 years of age category, 20% in the 65 years of age and over category, and 60% randomly selected among all households with predicted working telephone numbers. The representative sample of adult drivers refers to the large-scale, straight randomized sampling method employed to conduct the survey. The oversampling of the two hardest to reach populations (oldest and youngest) took place in addition to the selection of the general population sample. No weighting was employed to adjust for the different generation groups since the age group data were to be reported separately.

All respondents were asked to self-report their age on the survey and were grouped following data collection with analysis of all survey data conducted utilizing the self-reported age. The Virginia Tech Institutional Review Board (IRB) reviewed and approved all protocols for this study.

Voluntary consent was implied by survey respondents agreeing to proceed with the survey interview. Only adults age 18 and over were permitted to proceed with the survey interview. Screening questions confirmed that each respondent had a valid driver's license and drove at least once a week. Three hundred eighty-six respondents did not meet these criteria and were eliminated from the eligible sample pool. All telephone calls for the survey were conducted from September through November 2013 by trained CSR staff utilizing a Computer-Assisted Telephone Interviewing system.

CSR programmed all call scheduling such that each viable telephone number in the sample was attempted to be reached up to six times at different times of day on different days of the week. A total of 19,772 telephone numbers were called. Of these, 8177 potential respondents were excluded for a variety of reasons, including not answering the telephone after several attempts, non-working or non-residential telephone numbers, individual indicating that he or she was not a regular driver, a language or hearing barrier, or no adults residing in the household. This left a remaining sample of 11,595 potential respondents contacted, of which 1086 completed the interview, corresponding to a response rate of approximately 9% of all participants contacted.

Based on the total number of completed interviews, the survey has a sampling error of approximately ±3%. Therefore, in 95 out of 100 surveys completed with this number of interviews using the same sampling methodology and parameters, the results obtained would fall in a range of ±3% of the results that would be achieved if interviews were completed with every member of the target population. Smaller sampling errors are present for items on which there was polarized response (e.g., 90% identical response on an item).

2.3. Participants

Table 1 depicts the sample distribution across the main driving generations. There were 53 respondents who completed the survey but refused to report their age. Also, as only fourteen respondents were members of the Greatest Generation (i.e., over the age of 85), these individuals' responses were excluded, resulting in a total of 1019 responses included in analyses.

3. Results

Responses for all questions were analyzed using a chi-square (χ^2) test for independence, testing the null hypothesis that responses were distributed equally across generational groups. Significant χ^2 values were submitted to post hoc analysis using standardized Pearson residuals, which report each cell's goodness of fit between its actual and expected values. An alpha (α) level of $\alpha = 0.05$ was used for omnibus significance tests, and a threshold of 2 standard deviations (SD) beyond expected values was used for residual analyses.

We first present participant responses to questions about their comfort with and interest in general technology, followed by responses to questions about automobile-specific advanced technology and carry-in technology that could be incorporated into the driving environment. We then present participant opinions about CVS features, potential concerns about CVS, and overall acceptance of CVS technology. For all figures, cells with hashed lines indicate that that cell's value was more than 2 SD from expected as determined by the residual analysis. Responses of "Don't Know" and "Refused to Answer," are presented in all figures, although these were not included in any statistical analyses due to small cell sizes (expected values less than 5).

3.1. General & automotive technology

Participants were asked to rate their agreement with the statement "You are comfortable using current technology such as computers and smart phones." Results are presented in Fig. 2. Low expected frequencies in the *Somewhat Disagree/Strongly Disagree* response categories necessitated they be combined across participants into a general *Disagree* category. This

Table 1
Participant demographics.

		Millennials	Generation X	Baby Boomers	Silent Generation
Birth year range		1983–2001	1965–1982	1946–1964	1929–1945
Approximate age range		18–31	32–49	50–68	69–85
Number of respondents		78	298	392	251
Number contacted via mobile/landline/unknown		32/23/20	48/101/152	62/263/67	15/140/96
Mean participant age (*SD*)[a]		25 *(3)*	39 *(5)*	58 *(5)*	74 *(5)*
Gender	Female	42%	52%	55%	53%
	Male	58%	42%	45%	47%
Highest education attained	Elementary/Some HS	6%	1%	3%	3%
	HS	19%	12%	19%	22%
	Trade School	1%	1%	1%	1%
	Some College	26%	15%	14%	19%
	2-Year College	8%	7%	8%	8%
	4-Year College	28%	40%	30%	23%
	Graduate/Professional	9%	22%	26%	23%
Type of vehicle driven	Passenger Car	42%	43%	48%	63%
	SUV/Crossover	18%	29%	27%	20%
	Van/Minivan	3%	11%	6%	8%
	Truck	18%	13%	14%	9%
	Sports Car	18%	3%	3%	2%
Urban/rural	Urban	27%	20%	22%	29%
	Suburban	35%	48%	38%	39%
	Rural	24%	30%	36%	26%
	Other	6%	2%	2%	3%

[a] Among participants who reported their age. Participants not willing to do so were requested to identify their age range instead.

produced a significant value of $\chi^2(6, N = 964) = 151.78$, $p < .05$, indicating that there were differences among generations in their comfort levels with the current technology. Post-hoc Pearson residuals indicated that all generations differed significantly from expected values across response categories. The younger generations were more comfortable with current technology, and there was a marked split between the Millennial/Gen-X generations and the older (Boomer/Silent) generations in comfort with technology.

Participants were asked two questions about their general attitudes toward current in-vehicle technology. First, participants were asked to rate their level of agreement with the statement "You prefer your vehicle to have the newest technologies and options available." Responses are presented in Fig. 3, left. A chi-square test of independence was significant, $\chi^2(9, N = 989) = 24.24$, $p < .05$, indicating a difference in response distribution across generations. The Silent generation was least likely to desire the newest technologies and options, with under 50% expressing any level of agreement with that statement; they also had the largest share of *Strongly Disagree* responses, with nearly 30% of respondents expressing this view. Participants were then asked to rate their level of agreement with the statement "Modern in-vehicle technology is usually more distracting than useful;" results are presented in the right panel of Fig. 3. A chi-square test of independence indicated significant differences among generations, $\chi^2(9, N = 953) = 43.69$, $p < .05$. The Silent generation was most likely to feel that modern in-vehicle technology is more distracting than useful, with Gen-X being the least likely to agree.

3.2. Carry-in & integrated in-vehicle technologies

To understand how drivers across generations use smartphones in a driving context, participants were asked how often they use smartphones as navigation devices or music players when driving. In both cases, there were significant differences

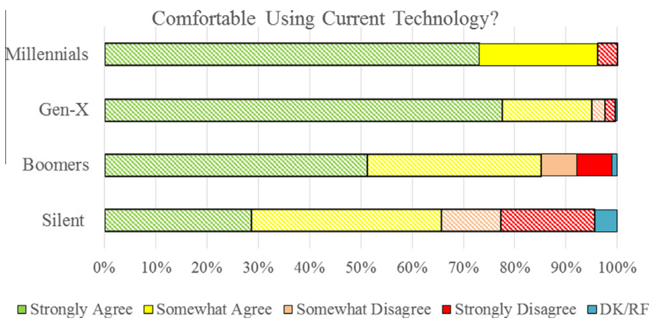

Fig. 2. General comfort with current technology.

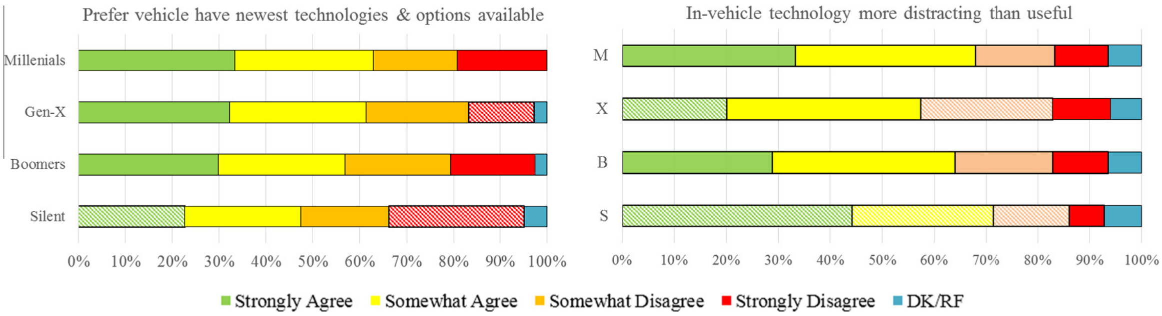

Fig. 3. Opinions on in-vehicle technology distraction and desirability.

found in response distribution across generations, $\chi^2(9, N = 1005) = 70.51$, $p < 0.05$ for navigation and $\chi^2(9, N = 1008) = 151.55$, $p < 0.05$ for music players (Fig. 4). Younger generations were much more likely to use smartphones as carry-in connected devices, as over 30% of respondents in both Millennial and Gen-X generations reported doing so *Often* or *Sometimes*, as opposed to less than 20% of Boomers and less than 10% of the Silent Generation.

In contrast, when asked about ownership and use of integrated advanced vehicle systems including navigation systems, backup cameras, internet connections, and collision warning systems, Millennials tended to be less likely to own these advanced technologies than respondents in older generations, although this trend was only significant for ownership of backup cameras ($\chi^2(3, N = 1017) = 11.84$, $p < .05$). Results are presented in Fig. 5. Among participants who did own advanced systems, there were no significant differences in the distribution of frequency of use for any technology except backup cameras, where Gen-X and Boomer participants had significantly different "*Use Rarely*" responses from expected, $\chi^2(4, N = 187) = 9.42$, $p < .05$ (Millennials were excluded from this post hoc analyses due to small cell size). These results suggest that, although older drivers may be more averse to advanced technology in general, including mobile devices, they are about as likely to own and use these technologies when integrated into their vehicles as younger generations.

3.3. Connected vehicle system features

Participants were asked their level of interest in several near-future CVS safety features. Majorities of respondents in all generational categories expressed that they were either *Very* or *Somewhat* interested in CVS that warn about potential road hazards and safety situations (Fig. 6). Over 70% of participants in all generations expressed some level of interest in all proposed systems, and over 80% of participants in all generations expressed interest in intersection hazard and stopped vehicle warning systems.

Significant differences in response distribution were found for the Oncoming Car Warning ($\chi^2(9, N = 1018) = 23.67$, $p < .05$), Stopped Vehicle Warning ($\chi^2(6, N = 1014) = 16.53$, $p < .05$), and Heavy Traffic Warning ($\chi^2(6, N = 1015) = 27.39$, $p < .05$) features, while no significant differences were found among group interest in the Intersection Hazard feature ($\chi^2(9, N = 1006) = 14.42$, $p > .05$). For the Oncoming Car and Stopped Vehicle warnings, Boomer respondents were more likely than expected to respond that they were *Very Interested*. These differences, however, tended to be small, and participants across all generations were in favor of these systems, along with the Intersection Hazard warning system. The largest discrepancies were found for the Heavy Traffic Warning, where Millennials were more likely and Silent Generation respondents less likely to report being *Very Interested*; however, this feature also had strong support across generations. For the Stopped Vehicle and Heavy Traffic Warning questions, *Somewhat Disagree* and *Strongly Disagree* were combined due to small expected cell counts.

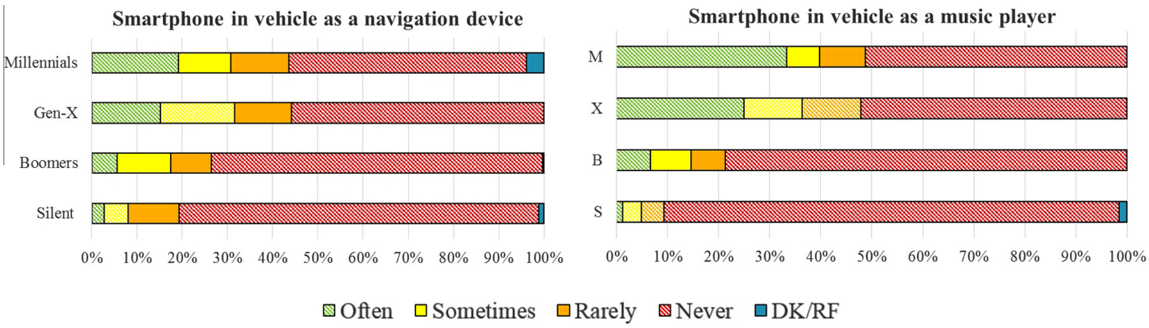

Fig. 4. Participant use of smartphones as carry-in connected devices.

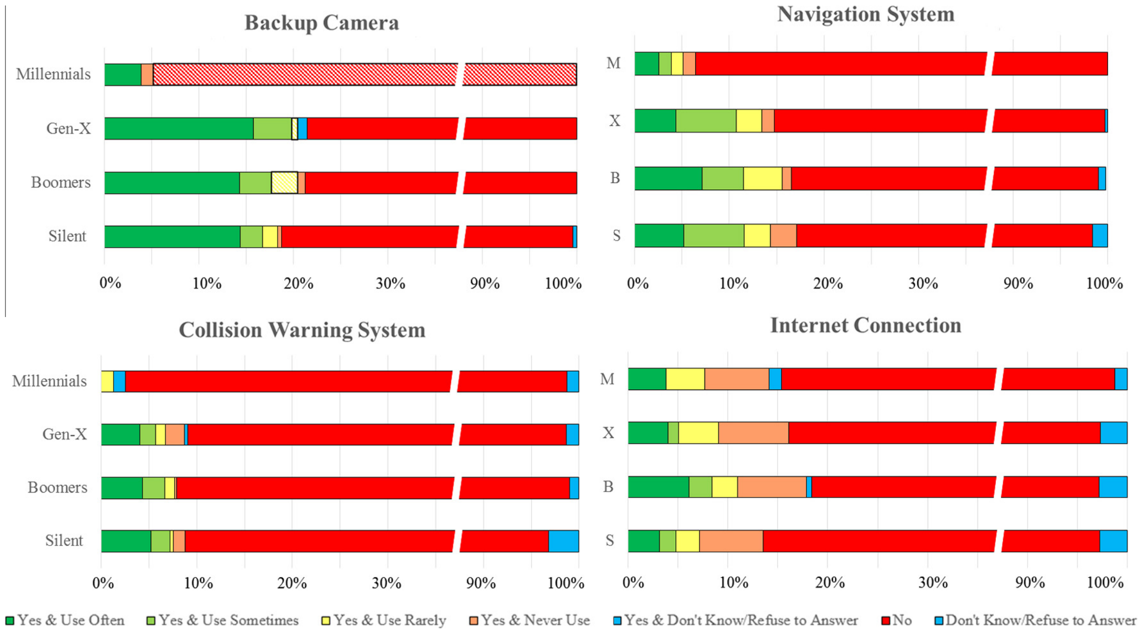

Fig. 5. Ownership & use of integrated vehicle technology.

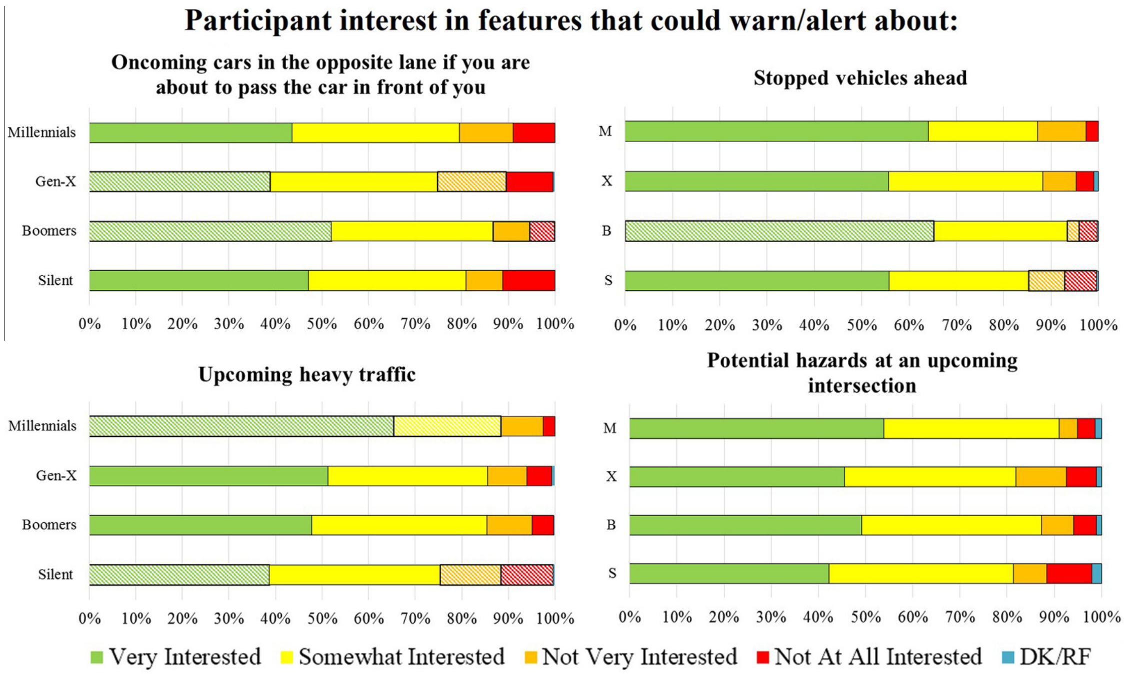

Fig. 6. Interest in safety-related CV features.

In contrast, participants reported much less interest in non-safety related CVS such as advertising and social media (Fig. 7). When asked about their level of interest in features that could offer discounts to nearby businesses, all generational groups except Millennials expressed less than 40% positive interest. There was a significant difference in response distribution across generations, $\chi^2(9, N = 1014) = 36.80$, $p < .05$, which was reflected in the Millennials' higher than predicted *Very Interested* response proportion (over 25%) and the Silent Generation's higher than predicted *Not at All Interested* response proportion (over 40%). There was also a significant difference in response distribution across generations for the question of interest in social media connectivity features, $\chi^2(6, N = 1016) = 26.79$, $p < .05$; for this test, *Very* and *Somewhat Interested*

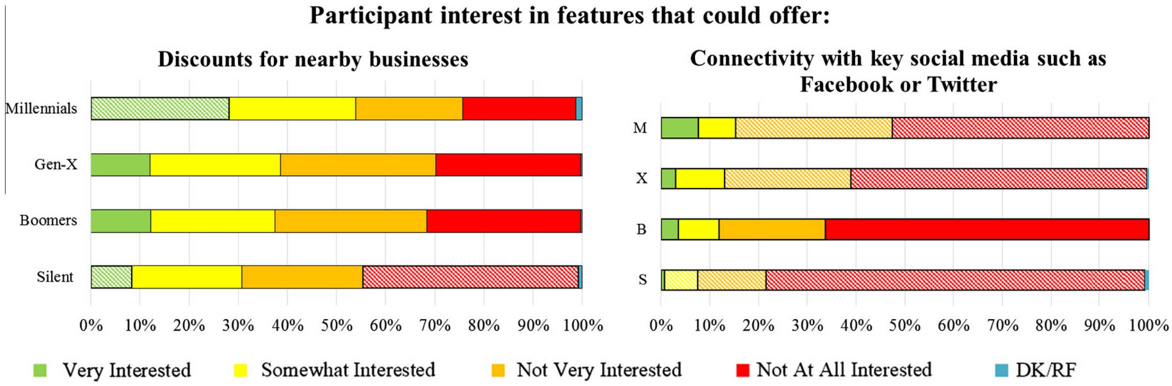

Fig. 7. Interest in other CV features.

response categories were combined due to small cell sizes. While no generation expressed more than 15% combined *Very* and *Somewhat Interested*, the Silent Generation was significantly more likely to report that they were *Not at All Interested*, and younger generations were relatively more interested. These results suggest that, while there is cross-generational support for safety-related CV features, there is less interest in advertising or social media features, particularly among members of the oldest generation, than in safety-related features.

3.4. Concerns about connected vehicle systems

Participants also responded to several questions about their level of concern regarding certain potential issues with CV technology, including data privacy, system security, and vehicle cost (Fig. 8). Respondents of all generations tended to report having concerns about issues of data access, security and system cost. The two questions that elicited a significant difference in response distribution across generations were "How concerned are you that someone could hack into the system and cause a traffic jam or crash?," $\chi^2(6, N = 1005) = 21.09$, $p < .05$, and "How concerned are you that someone could hack into the system and access personal information?," $\chi^2(6, N = 1014) = 22.45$, $p < .05$; for both questions, responses in the *Somewhat* and *Very Concerned* categories were condensed for analysis due to small numbers of responses. For both of these questions, over 80% of respondents in the oldest two generations reported being *Somewhat* or *Very Concerned*, while the concern level was approximately 75% for the two younger generations.

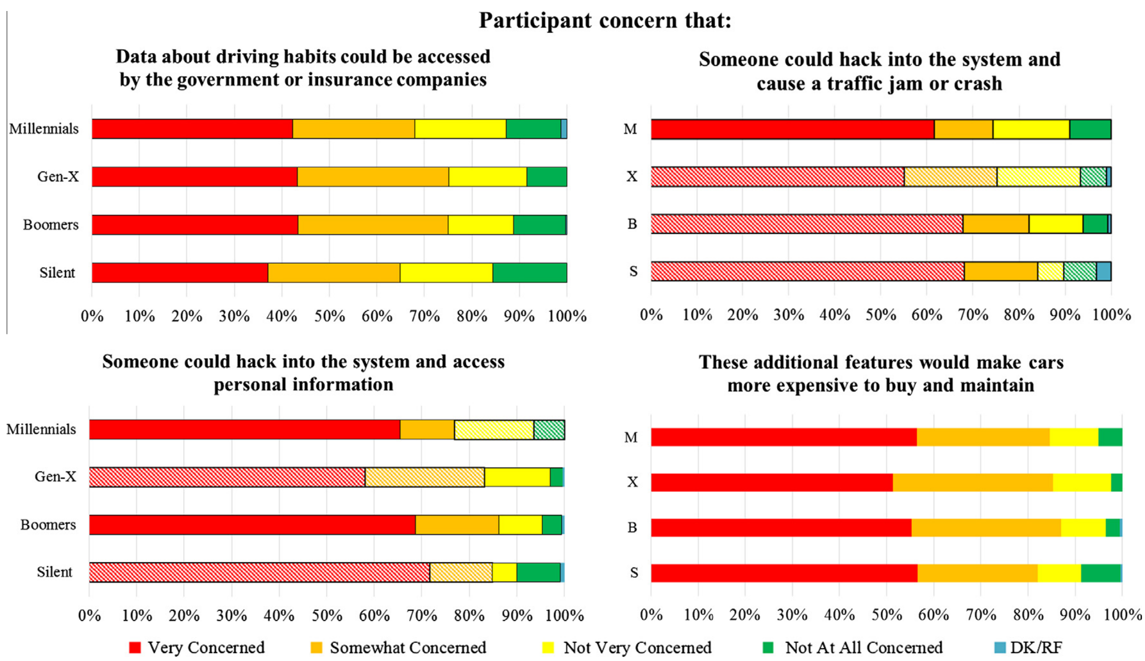

Fig. 8. Concerns about CV systems.

3.5. Overall acceptance of connected vehicle systems

Finally, participants were asked about their overall level of comfort and acceptance of CVS technology (Fig. 9). Significant differences in response distribution were found in the extent to which participants agreed with the statements "*You would be comfortable with this type of system if you were assured your personal data would be kept secure*" ($\chi^2(9, N = 1004) = 21.21$), $p < .05$ and "*You would be accepting of such a system on our roadways*" ($\chi^2(9, N = 997) = 53.76$, $p < .05$). There was a monotonic relation between age and overall acceptance of CVS, with the youngest generation being the most comfortable with and accepting of CVS, and the oldest being the least comfortable and accepting. Significant deviations from expected cell sizes were found for the *Strongly Disagree* response category for both questions, with the oldest generation being significantly more likely to disagree with these statements than the younger generations, particularly the Millennials.

4. Discussion

This study demonstrates that the construct of generations provides a meaningful prism though which the issue of technological acceptance can and should be investigated. Results suggest a complex relationship between generational membership and driver attitude toward advanced in-vehicle technology. Members of the Silent Generation tended to report being the least likely to be comfortable with and accepting of modern, advanced, and near-horizon future technology, and least likely to use carry-in technology such as smartphones in the driving environment. However, members of this generation also tended to use advanced in-vehicle technology such as navigation systems, collision warning systems, and backup cameras at rates similar to Gen-X and Boomer generations, and at a higher rate than Millennials. These findings suggest that current seniors may be more cautious with and hesitant to adopt new vehicle technology, but that they do not necessarily avoid it, and may be willing to use it regularly if it is well designed with a reasonably short learning curve that allows drivers to readily acquire experience with it. It is a limitation of this study that there were too few members of the Greatest Generation (currently aged 86 and older) to draw conclusions about their opinions, as there are currently over 3 million drivers on the roadways in this age group (Federal Highway Administration, 2015), and this number will continue to grow.

Millennials and Gen-X respondents, in contrast, were the most comfortable with and enthusiastic about modern technology, particularly carry-in devices. The relatively low level of Millennial ownership and use of advanced vehicle technology may be due to their inability to afford these types of vehicles or technology packages relative to the older generation cohorts. Gen-X respondents, having come of age during the computer, cell phone, and portable GPS revolutions of the 1980s and 1990s, were the most likely to use both carry-in and in-vehicle technology, the most likely to be comfortable with modern technology, the least likely to think technology is more distracting than useful, and (along with Millennials) were most likely to want their vehicles to have the newest technology. Because of their comfort with and interest in technology, this generation may be the most likely to benefit from CVS and may be most critical to its general acceptance in the market. In the future, they may be the first generation of seniors to be readily adaptable to rapid advances in vehicle technology. However, since for the present Millennials appear both ready to incorporate technology into the driving task but less able to afford vehicles with integrated technology, special attention must be paid to the usability concerns and the potential for distraction of nomadic devices like GPS navigation systems and smartphone apps (including navigation) that are intended for use while driving. As a substantial body of research has found, distraction by secondary tasks is a major factor in crashes for young drivers (e.g. Buckley, Chapman, & Sheehan, 2014; Klauer et al., 2014).

Boomers often fell between Gen-X and the Silent Generation in response profile. They were among the groups most strongly in support of safety-related CVS, and, while less likely than Millennials or Gen-X respondents to use carry-in technology when driving, were significantly more likely to do so than the Silent Generation. Further, Boomers were consistently among the most concerned about potential negatives associated with CVS. These results suggest that this generation is less enthusiastic and comfortable with technology than younger generations, but is more engaged with and aware of the issues

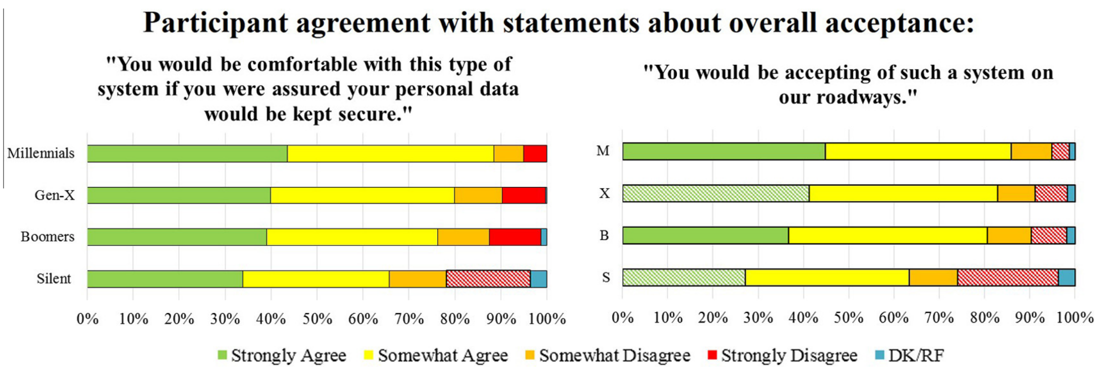

Fig. 9. Acceptance of CVS.

surrounding technology than the older driving generation. This makes sense from a generational perspective, as their formative years were prior to the personal computing revolution, but a significant proportion of their adult life has been spent interacting with changing technology.

Overall, there was cross-generational enthusiasm for safety-related CVS, with majorities of participants in all generations expressing that they were *very* or *somewhat* interested in all the safety features presented, and very few differences were found across generations on this topic. However, there was substantially less interest in features not related to driving safety, such as advertising or social media connectivity. While younger generations were more likely to be interested in these non-safety systems than older generations, fewer than 60% of respondents in any generation (and fewer than 40% of participants in the three oldest generations) responded that they were *very* or *somewhat* interested in advertising-related features. More than 50% of respondents in all groups (including nearly 80% of the Silent Generation) responded that they had no interest in social media features.

There was also cross-generational consensus on areas of concern regarding CVS; in this case, majorities of participants of all generations expressed concerns about costs and data security. Few significant differences were found among generation response distributions on these questions. Over 70% of respondents in all generations reported that they were *very* or *somewhat* concerned that CVS technology would increase vehicle and/or maintenance costs, and over 60% of all respondents expressed concern that their data could be accessed inappropriately, whether collected legally by the government or insurance companies, or illegally by hackers. Similarly, there was cross-generational concern that hackers could access the system and interfere with traffic. These findings suggest that concerns over data security and cost are commonplace across all age groups, and that implementation of such systems should proceed cautiously with these issues in mind.

Finally, there was a significant relationship between respondent generation and overall comfort with and acceptance of CVS. For all four generations, over 60% of respondents reported that they *strongly* or *somewhat* agreed that they would be comfortable with CVS if their data were secure, and that they would be accepting of such systems on our roadways. However, fewer than 30% of respondents in the Silent Generation reported *strongly* agreeing that they would be accepting of CVS on our roadways; in contrast, approximately 45% of Millennials *strongly agreed*. Further, over 20% of the Silent Generation respondents *strongly disagreed* with the statement that they would accept CVS on our roadways, compared to fewer than 4% of Millennial respondents who *strongly disagreed* with this statement.

Overall, these responses are consistent with the hypothesis that generations that grew up regularly using and driving with computerized technology are more willing and able to accept advanced technology in vehicles than those who did not. A median-age member of the Silent Generation had entered middle age by the time PCs became popular, and may not have incorporated computing technology into his/her everyday life to the extent that younger generations who grew up with it have. Similarly, members of the Baby Boomer generation may not have incorporated communication technologies like smartphones and email into their lives to the extent that younger generations have. This lack of experience during the early, formative periods in one's life may lead to a lifelong disadvantage when dealing with specific technology, as the parent of any child who understands computers better than he or she does may attest. In contrast, today's children are growing up in a world dominated by computing-intensive technology with a wide variety of interfaces and capabilities, including PCs, tablets, smartphones, and video game consoles, many of which connect to the internet and to each other (American Academy of Pediatrics, 2013). When the current generation of young children is learning to drive in a decade or so, many will have experience manipulating technology that outstrips even the current generation of novice drivers.

Schoettle and Sivak (2014) recently conducted a similar survey in the same timeframe as the research presented here, but focusing more on comparing the responses across three countries (U.S., U.K., and Australia) than across the driving generations. However, it is interesting to note that their findings mirrored those reported here in several key ways. Their respondents were also concerned about system and data security, and they also felt that safety applications were the most important. Most participants in the Schoettle and Sivak (2014) study reported that it was at least moderately important that CVS include internet connectivity. Respondents in the current study were less enthusiastic about this aspect of CVS, though the question was phrased in terms of social media rather than general internet connectivity. Participants in both studies indicated substantive concern over costs. Those in the current study indicated a relatively high degree of concern over vehicle and tax related costs, while over 40% of participants in the Schoettle and Sivak (2014) study indicated that they would not be willing to pay any additional amount to have CVS in their vehicles.

5. Future research

The distinction between the physiological challenges that each succeeding generation of seniors face, which may be relatively constant across time, and the level and type of technological experience to which each generation is exposed, which varies widely across time, deserves to be studied further and incorporated into the ongoing design of advanced vehicle systems. In addition, future work could benefit from further investigation into the interplay between individual experience with system operation, including experience with reliability and trust, and their relationship to that individual's enthusiasm for advanced vehicle technology. This could be conducted via further survey research or in an experimental setting where interactions between users of differing generations and technology could be directed and explored. Finally, CVS represents just one avenue of technological improvement on the roadways. Another nascent area of innovation is automated vehicles, with the federal government, auto manufacturers, and even Google having expressed support for vehicles with partial or full automation. The possibilities for interaction between aging drivers and autonomous vehicles, as well as the potential independence-related benefits of such vehicles for drivers with a variety of age-related (and non-age related) disabilities, is well deserving of further study.

6. Limitations

There are several limitations to this study that should be noted. First, while the response rate of 9% was in line with the national average telephone survey response rate (The Pew Research Center For The People, 2012), it is possible that the sample of respondents agreeing to participate contained a self-selection bias. In addition, due to the time constraints of a telephone survey, it was not possible to fully explain the costs and benefits of novel technologies. We attempted to balance questions to quantify participant attitudes about positive and negative aspects of CVS technologies, but, as noted above, future research could delve more deeply into the usability and acceptance aspects of such technology using experimental or focus-group methodologies. Finally, as noted above, we were not able to get sufficient respondents of the Greatest Generation to obtain statistical significance.

7. Conclusion

The findings presented here concerning advanced and connected vehicle technology acceptance and comfort mirror driver attitudes toward general and advanced automotive technology. The older driving generations tended to be less comfortable and more hesitant to engage with advanced technology, more likely to find it more distracting than useful, and less likely to want it in their vehicles than respondents of younger generations, particularly Millennial and Gen-X generations. However, even though a minority of Silent Generation drivers owned vehicles with advanced technology, their rates were similar to Boomers and Gen-X drivers, and those who owned advanced vehicle technology also used it at about the same rates as drivers in younger generations. Coupled with cross-generational interest in CVS safety features, this suggests that current older drivers may be open to using advanced connected technology, but it will most easily be accepted by all drivers – and members of the Silent Generation in particular – if its initial scope is limited to well-designed safety-related applications.

CVS technologies are rapidly emerging. This survey helps to reveal the different ways they may be perceived and accepted across the driving generations, and how they may be viewed as the current driving population ages. As the oldest generations may benefit the most in some ways from such technology, and would only experience these benefits if they actively and correctly use the systems, it is imperative that designers and regulators consider these differences in the earliest establishment of designs and guidelines. Likewise, since seniors may often have unique driving challenges related to the physical, cognitive and perceptual effects of aging, reaching out to educate them about the benefits of CVS technology is also of importance in its successful implementation.

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References

American Academy of Pediatrics (2013). Children, adolescents, and the media. *Pediatrics, 132*(5), 958–961. http://dx.doi.org/10.1542/peds.2013-2656.

Brugeman, V. S., Wallace, R., & Cregger, J. (2012). *Public perceptions of connected vehicle technology*. Michigan Department of Transportation and Center for Automotive Research.

Buckley, L., Chapman, R. L., & Sheehan, M. (2014). Young driver distraction: State of the evidence and directions for behavior change programs. *Journal of Adolescent Health, 54*, 516–521.

Carlson, E. (2009). 20th-Century U.S. generations. *Population Bulletin, 64*(1). Population Reference Bureau.

Charness, N., & Boot, W. R. (2009). Aging and information technology use: Potential and barriers. *Current Directions in Psychological Science, 18*(5), 253–258. http://dx.doi.org/10.1111/j.1467-8721.2009.01647.x.

Cody, M. J., Dunn, D., Hoppin, S., & Wendt, P. (1999). Silver surfers: Training and evaluating internet use among older adult learners. *Communication Education, 48*(4), 269–286.

CTIA – The Wireless Association (2014). *Annualized Wireless Industry Survey Results – December 1985 – December 2013*. <http://www.ctia.org/docs/default-source/Facts-Stats/ctia_survey_ye_2013_graphics-final.pdf?sfvrsn=2. Retrieved March 26, 2014.

Czaja, S. J., Fisk, A. D., Hertzog, C., Rogers, W. A., Charness, N., Nair, S. N., & Sharit, J. (2006). Factors predicting the use of technology: Findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and Aging, 21*(2), 333–352.

Dobbs, B. M. (2008). Aging baby boomers – A blessing or challenge for driver licensing authorities. *Traffic Injury Prevention, 9*, 379–386.

Federal Highway Administration (2015). *Highway statistics 2013: Distribution of licensed drivers*. <http://www.fhwa.dot.gov/policyinformation/statistics/2013/dl20.cfm>.

Flynn, K. E., Smith, M. A., & Freese, J. F. (2006). When Do Older Adults Turn to the Internet for Health Information? Findings from the Wisconsin Longitudinal Study. *Journal of General Internal Medicine, 21*, 1295–1431.

Harrod, M. (2011). "I have to keep going": Why some older adults are using the internet for health information. *Ageing International, 36*, 283–294.

Intelligent Transportation Systems Joint Program Office (2013a). Research and Innovative Technology Administration, U.S. DoT: <http://www.its.dot.gov/factsheets/safety_pilot_factsheet.htm#sthash.so9N5MOq.dpuf>.
Intelligent Transportation Systems Joint Program Office (2013b). Research and Innovative Technology Administration, U.S. DoT: <http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm> Accessed 3/7/2014.
Klauer, S. G., Guo, F., Simons-Morton, B. G., Oimet, M. C., Lee, S., & Dingus, T. (2014). Distracted driving and risk of road crashes among novice and experienced drivers. *The New England Journal of Medicine, 370*, 54–59.
Media.Cadillac.com (2014). *Cadillac to Introduce Advanced 'Intelligent and Connected' Vehicle Technologies on Select 2017 Models*. <http://media.cadillac.com/media/us/en/cadillac/news.detail.html/content/Pages/news/us/en/2014/Sep/0907-its-overview.html> Retrieved September 9, 2014.
National Safety Council (2008). *Senior Drivers to Increase 70% Over Next 20 Years*, <http://www.nsc.org/Pages/SeniorDriverstoIncrease70OverNext20Years.aspx>.
National Highway Traffic Safety Administration (2014). *U.S. Department of Transportation Announces Decision to Move Forward with Vehicle-to-Vehicle Communication Technology for Light Vehicles.* <http://www.nhtsa.gov/AboutNHTSA/Press+Releases/2014/USDOT+to+Move+Forward+with+Vehicle-to-Vehicle+Communication+Technology+for+Light+Vehicles>.
Owens, J. M., & Antin, J. F. (2014). *Cross-generational attitudes toward general and advanced vehicle technologies*. Final Report submitted to NHTSA in partial fulfillment of Contract DTNH22-11-D-00236.
Rainie, L., & Smith, A. (2013). *35% of Those Ages 16 and Older own Tablet Computers. 24% Own E-Book Readers.* <http://www.pewinternet.org/files/old-media//Files/Reports/2013/PIP_Tablets%20and%20e-readers%20update_101813.pdf> Retrieved.
Rosenberg, L., Kottorp, A., Winblad, B., & Nygard, L. (2009). Perceived difficulty in everyday technology use among older adults with or without cognitive deficits. *Scandinavian Journal of Occupational Therapy, 16*(4), 216–226.
Ryder, N. B. (1965). The cohort as a concept in the study of social change. *American Sociological Review, 30*(6), 843–861. http://dx.doi.org/10.2307/2090964.
Salthouse, T. A. (2000). Aging and measures of processing speed. *Biological Psychology, 54*, 35–54. http://dx.doi.org/10.1016/s0301-0511(00)00052-1.
Schoettle, B. S. & Sivak, M. S. (2014). *A Survey of Public Opinion about Connected Vehicles in the U.S., the U.K., and Australia.* University of Michigan Transportation Research Institute. UMTRI-2014-10. <http://hdl.handle.net/2027.42/106590>.
Shapira, N., Baraka, A., & Gal, I. (2007). Promoting older adults' well-being through Internet training and use. *Aging & Mental Health, 11*(5), 477–484. http://dx.doi.org/10.1080/13607860601086546.
Stutts, J., Martell, C., & Staplin, L. (2009). *Identifying behaviors and situations associated with increased crash risk for older drivers.* National Highway Safety Traffic Administration Report, DOT HS 811 093. <http://www.nhtsa.gov/DOT/NHTSA/Traffic%20Injury%20Control/Articles/Associated%20Files/811093.pdf>.
The Pew Research Center For The People & The Press (2012). *Accessing the representativeness of Public Opinion Surveys.* Washington, D.C. <http://www.people-press.org/files/legacy-pdf/Assessing%20the%20Representativeness%20of%20Public%20Opinion%20Surveys.pdf>.
U.S. Census Bureau (2012). Population Projections – 2012 National Population Projections: Summary Tables. <https://www.census.gov/population/projections/data/national/2012/summarytables.html> Accessed 3/21/2014.
Wagner, N., Hassanein, K., & Head, M. (2010). Computer use by older adults: A multi-disciplinary view. *Computers in Human Behavior, 26*, 870–882. http://dx.doi.org/10.1016/j.chb.2010.03.029.
Wood, J. (2002). Aging, driving, and vision. *Clinical and Experimental Optometry, 85*(4), 214–220. http://dx.doi.org/10.1111/j.1444-0938.2002.tb03040.x.
Zickuhr, K., & Madden, M. (2012). *Older Adults and Internet Use.* Pew Research Center, Washington, D.C. <http://www.pewinternet.org/files/old-media//Files/Reports/2012/PIP_Older_adults_and_internet_use.pdf> Retrieved.