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Auditory Interfaces in Automated Driving: an International Survey

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Abstract: This study investigated peoples' opinion on auditory interfaces in contemporary cars and their willingness to be exposed to auditory feedback in automated driving. We used an Internet-based survey to collect 1,205 responses from 91 countries. The participants stated their attitudes towards two existing auditory driver assistance systems, a parking assistant (PA) and forward collision warning system (FCWS), as well as towards a futuristic augmented sound system (FS) proposed for fully automated driving. The respondents were positive towards the PA and FCWS, and rated their willingness to have these systems as 3.87 and 3.77, respectively (1 = disagree strongly, 5 = agree strongly). The respondents tolerated the FS. The results showed that a female voice is the most preferred feedback mode for the support of takeover requests in highly automated driving, regardless of whether the respondents' country is English speaking or not. The present results could be useful for designers of automated vehicles and other stakeholders.

Practitioner Summary: In an Internet-based questionnaire peoples' opinion on auditory interfaces in contemporary cars and their willingness to be exposed to auditory feedback in automated driving were evaluated. The results showed that a female voice is the most preferred feedback mode for the support of takeover requests in highly automated driving.

Keywords: Survey, Questionnaire, Crowdsourcing, Driverless car, Fully automated driving, Highly automated driving

Introduction

The development of Automated Driving Systems

The development of automated driving technology is one of the key topics in modern transportation research. A transition to automated driving may have a large positive influence on society [1,2]. Each year more than 1,000,000 fatal accidents occur on roads worldwide, with the lower-income countries being overrepresented [3,4]. If automated driving systems are designed to be fully capable and reliable, such technology could prevent a very large portion—yet probably not all—of road traffic accidents [5]. Furthermore, traffic congestions, gas emissions, and fuel consumption may reduce considerably because of automated driving systems.

The control of vehicles can be represented as a spectrum consisting of five levels: (1) manual driving, (2) driver assistance, (3) partially automated driving, (4) highly automated driving, and (5) fully automated driving [6]. The introduction of driver assistance systems (i.e., level 2 automation) to the public took place in 1995, with the release of adaptive Cruise Control (ACC), a system that automates the vehicle's longitudinal motion [6]. Advancements in cameras, radars, lasers, and artificial intelligence have led to the creation of systems that make partially automated driving (i.e., level 3 automation) possible. Partially automated driving systems not only control the longitudinal motion of a

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vehicle, but also its lateral motion. Examples of such systems are BMW's Traffic Jam Assistant [7], Volvo's ACC with steer assistance [8], and Mercedes' Distronic Plus with Steering Assist [9]. In partially automated driving, drivers are usually required to keep their eyes focused on the road and intermittently touch the steering wheel.

Highly automated driving (HAD; level 4 automation) is a next step. In HAD, the human can release the hands from the steering wheel and is no longer required to monitor the road permanently [10]. However, humans still have an important role in the control of highly automated vehicles [11–13]. In HAD, drivers can be asked to take over control of the vehicle when required, for example, when the vehicle automation cannot solve a task in a demanding traffic environment. The time between issuing a 'takeover request' and the required moment of transition of control from the vehicle to the human is a critical design parameter [14,15]. If the driver spends too much time on reclaiming the control of the vehicle, or if the driver does not comprehend the warning signal sent by the vehicle, an accident may result. Clearly, the design of appropriate feedback is essential for the successful introduction of HAD to the public roads. Indeed, inappropriate feedback is regarded as a primary cause of automation-induced accidents [16].

Fully automated driving (FAD; level 5 automation) will be the next and final iteration of automated driving (level 5 automation). People have been envisioning this step in the development of transportation for a long time. Almost half a millennium ago, Leonardo Da Vinci envisioned a pre-programmed clockwork cart [17]. In 1939 during the New York World's Fair, General Motors presented their vision of the world 20 years into the future (1959–60) in their Futurama exhibition, where they introduced a concept of automated highways with trench-like lanes for separating traffic [18]. In 1953, the futurist Isaac Asimov wrote a short story 'Sally' that pictured a future situation where only cars that do not require a human driver are allowed on the roads.

FAD offers numerous potential benefits. It could reduce stress and allow the operator to engage in non-driving tasks such as working or resting [19]. Furthermore, full automation is a recommended solution to reach an optimization of traffic flow [20], something that can be achieved by means of platooning on highways [21]. The Google Driverless Car is one of the existing prototypes of FAD [22]; however, this particular vehicle pretends to comply with the principles of FAD; in actuality the Google Driverless Car relies on accurate three-dimensional maps of the environment and currently cannot cope with all dynamic environments of high complexity. It requires considerable advances in sensing and artificial intelligence before FAD will become practically feasible on all public roads. Continental, a leading German manufacturer specialising on components for automotive industry, predicts that fully automated driving will be launched in the year 2025 [23], whereas some voices have argued that FAD will never happen [24–26].

Although automated driving systems are expected to improve safety, certain side effects may occur regarding the human factor. A degradation of awareness of the environment was found among drivers exposed to ACC [27,28], and may also be expected to occur in higher levels of automated driving. Furthermore, it is expected that people who will be driving highly and fully automated cars will suffer from a reduction of their manual control skills, similar to pilots in highly automated airplanes [29,30]. Additionally, in automated driving, a degradation of situation awareness and a reduction of mental workload is foreseen [31]. The development of effective feedback systems is considered important in supporting operator's sustained attention, also called vigilance [32]. The present survey study aimed to gather the opinion of people on preferred modalities and feedback types in HAD and FAD.

Auditory Displays

As mentioned above, unless the driving task is fully automated, an appropriate feedback system is required that warns and/or informs the human when automation mode changes are required. The present study investigated the potential of auditory feedback in automated driving. The auditory modality has three important characteristics: (1) the auditory modality is omnidirectional. That is, auditory cues can be received from any direction, (2) the auditory sense can receive information at almost all times, (3) sound is transient, that is, unlike visual information which can be continuously available, information passed in the form of sound is only available at that particular moment [33]. Another advantage of sound is that you can use language, which may be more informative as compared to using haptic or visual interfaces. Because of the aforementioned qualities of sound, auditory displays are used in a variety of applications, especially in cases where the user needs to be alerted, or in cases where additional visual load has to be avoided. For example, the majority of present route navigation devices use voice and sound messages to give directions to their users [34], and flight crews use auditory cues to learn about proximate aircraft [35] and to obtain directional cues [36]. An auditory interface in combination with tactile feedback was suggested in a driving simulator study [37] as an optimal warning system for collision avoidance. The auditory modality has potential not only as a warning/alerting method, but also for providing inputs to the machine (e.g., speech interfaces). Literature reviews [38,39] suggest that people driver 'better' (i.e., less lane variation, steadier speed) when auditory interfaces are employed in a manually driven car. Visual interfaces may not be particularly useful for the implementation of warning signals in cars. Previous research has shown that imposing a large visual load on drivers can negatively affect their lane keeping performance [40] and alertness [41].

Auditory feedback can be delivered as a pre-recorded voice or as artificial sound warnings/messages. An example of pre-recorded auditory messages is an earcon (e.g., the sound of a bell), which people relate to certain events and objects that produce the sound of the icon [42,43]. It is known that a female voice is generally favoured over a male voice [44]. Furthermore, national or cultural differences seem to exist, where in some cases, the male voice is preferred over the female voice. In 2010, BMW had to recall its navigating system in Germany because male drivers disliked the idea of following orders produced by the female voice [45], and Apple recently added the male voice to their voice control system Siri [46]. In a driving simulator study by Jonsson and Dahlbäck [47], non-native speakers of English responded more accurately to route instructions provided by a female voice than to route instructions provided by a male voice.

Auditory Systems in Current Vehicles: Parking Assistant and Forward Collision Warning System

Modern vehicles often include Advanced Driver Assistance Systems (ADAS) that assist in driving and increase road safety. ADAS support drivers by providing auditory/visual/haptic warning messages intended to reduce the risk of having an accident, by guiding the driver, or by taking over control of some of the driving tasks. In the present survey, we first investigate the opinion of people on two existing auditory systems: a parking assistant (PA) and a forward collision warning system (FCWS).

There are 990 car models available with a PA feature available today, as recorded in November 2014 [48]. The first generations of PA (parking sensors) represent systems that produce warning sounds (beeps) when the car gets too close to a nearby object while parking, using ultrasonic or electromagnetic sensors [7,49,50]. Some recent PAs take over the positioning of the vehicle during parking, leaving the control over acceleration and deceleration to the driver [49], or take over control of the whole process entirely, as can be seen in the Toyota Prius 2015 and BMW X5 [50,51].

A FCWS is a system that provides a warning sound when a vehicle is rapidly approaching a vehicle in front. FCWS has the potential to prevent up to 42% of rear-end collisions [52–54]. If a potential accident is detected by the FCWS, the system either gives an auditory and/or visual warning to a driver [55] or engages in emergency braking and/or steering away from the object [56]. Most FCWS detect vehicles with the help of computer vision [57,58] (an approach which is used by companies like Honda and BMW [7,55,56]) and/or radars [55,56,59,60]. Both of these approaches have their limitations, and the system may not issue warnings or stop the vehicle in bad weather when the sensors are obscured by external factors. The introduction of vehicle-to-vehicle (V2V) communication may allow to increase the efficiency of FCWS and facilitate adaptive FCWS [61]. 88% of owners of Volvo cars surveyed in [62] reported always having the Volvo's version of FCWS turned on.

It is expected that both PA and FCWS will remain in future partially and highly automated vehicles. However, these systems will become obsolete with the introduction of FAD because both parking and collision avoidance will be handled without any interaction from humans.

'Augmented / Spatial' Sound System for Fully Automated Driving

Auditory warning signals will not be required in FAD, because in FAD the automation by definition takes care of all possible emergency conditions. This study proposes an experimental setup aimed at the 3D augmentation of sound surrounding a vehicle, hereafter referred to as the 'future system' (FS), which could be used in FAD for entertainment and comfort. Three-dimensional sound is being developed as a new instrument for providing feedback to humans [63,64] [65–67].

Our proposed FS filters unwanted sounds (e.g., tire/engine noise coming from vehicles in the vicinity) and amplifies desired sounds (e.g., sound of birds singing in a park). We envision that such a system could be used in future fully automated vehicles. Vehicles driving fully automatically must incorporate the full control of processes taking place in the vehicle and have full detection capabilities of the environment. Drivers of such vehicles will not be required to pay attention to the processes that take place in the environment surrounding the car. Hence, a spatial augmentation of sounds that a driver prefers to hear and simultaneous cancelation of unwanted sounds may enhance the experience of being engaged in FAD. Such system will probably have to be configurable: drivers must have an option to choose which sounds they want to augment and which sounds they wish to filter out, as well as the volume of particular reproduced sounds. The implementation of such system may lead to changes in the traffic regulation and warning systems of emergency vehicles, as drivers may wish to filter out the sounds of vehicles of other participants, including ambulances, fire trucks, and other vehicles utilised by emergency services.

The Aim of the Present Survey Study

As mentioned above, feedback is important in HAD, especially regarding transitions of control. It is clearly relevant for the development of automated driving systems to know what types of interfaces people want and need in order to develop safe and pleasant human-machine interaction. Because fully automated cars do not exist yet, it is impossible to test such research questions in an ecologically valid environment, except through driving simulator research (cf. [15,68–71]).

The present study was undertaken from a different point of view. We proceeded on the basis that respondents were asked to *imagine* future HAD and FAD scenarios, and accordingly, indicate preferred modalities and feedback types. We investigated the opinion of people on two existing auditory displays (PA & FCWS) as well as the experimental augmented sound system 'FS'. The respondents were asked to judge two qualities of the systems—helpfulness and annoyance—and state whether they would consider using such systems in the future. In addition, we asked people to report their preferred type of feedback for takeover requests in HAD. Statistical associations between self-reported driving style as measured with the Driver Behaviour Questionnaire (DBQ), yearly mileage, numbers of accidents, and opinions of respondents on the qualities and (dis)advantages of the proposed systems were assessed. Results of these analyses were compared with findings from two previous surveys that asked questions related to different aspects of the automated vehicles [72,73]. The hypothesis that people from non-English speaking countries prefer a female voice to a male voice in automated driving systems was also tested.

Additionally, the respondents were asked to provide their general thoughts on the concept of automated driving in a free-response question. Finally, the participants of the survey provided their opinion on the year of introduction of fully automated driving in their countries of residence.

Methods

Survey

A survey containing 31 questions was developed with the online tool CrowdFlower (www.crowdflower.com). Table 1 shows the questions of the survey as well as the corresponding coding. The full survey is included in the supplementary material. The survey was targeted towards reasonably-educated persons without knowledge of automated driving. A previous survey indicated that people who work on CrowdFlower-based surveys have mostly an undergraduate degree [73].

The present survey introduced three levels of driving: manual driving, partially automated driving, and fully automated driving in plain language. Manual driving was referred to as "normal (non automated) cars". The explanation of partially driving was provided as follows: "Imagine again that you are driving in an automated car (that can perform certain tasks without any interaction from the humans in the car). However, the automation cannot handle all possible situations, and you sometimes have to take over control". Respondents were asked to imagine fully automated driving as follows: "Imagine a fully automated car (no steering wheel) that drives completely on its own with no manual interaction".

The survey contained questions on the person's age, gender, driving frequency, mileage, and accident involvement. The questions asking participants to provide information on their driving style were based on the violations scale of the DBQ, as used by De Winter [74].

The respondents were asked to express their opinion on two currently existing systems and one proposed setup that could be used during fully automated driving. Specifically, we asked respondents about 1) a parking assistant (PA) in a manually driven car that produces warning sounds (beeps) when the car gets too close to a nearby object while parking, and 2) a forward collision warning system

(FCWS) in a manually driven car that provides a warning sound when a car is rapidly approaching another car in front, and 3) a future augmented surround sound system in a fully automated vehicle (FS). Illustrations belonging to the three scenarios (i.e., PA, FCWS, FS) were used in the survey (Figure 1). No auditory examples were used. The illustrations were uploaded to a remote site in order to be embedded to the survey. Supplementary material contains the XML code used to create the survey. If one wishes to add images to a CrowdFlower survey, the suggested method could be used.

a) b) c)

Figure 1. Illustrations belonging to the three scenarios presented to respondents. (a): Parking assistant (PA); (b): Forward collision warning system (FCWS); (c): Future system (FS).

In the survey the respondents were required to indicate any disadvantages of the PA, FCWS, and FS, respectively (Q17, Q23, & Q26). The participants also had the opportunity to indicate the preferred mode of feedback for receiving a takeover request (Q27 & Q28). In the last question (Q31), they were asked to "provide any suggestions, which could help engineers to build safe and enjoyable automated cars". Giving a response to this free-response question was optional. All examples of given comments shown in this article are direct quotes from the responses; no grammatical or syntactical mistakes were corrected. The participants had to complete all questions, but each question had a *I prefer not to respond* response option.

Table 1. All survey items

Variable	**Question**	**Full question as reported in the survey**	**Used coding**
Instr	Q1	Have you read and understood the above instructions?	1 = Yes, 2 = No
Gender	Q2	What is your gender? (1 = female, 2 = male)	-1 = I prefer not to respond, 1 = Female, 2 = Male
Age	Q3	What is your age?	Positive integer value
DriveFreq	Q4	On average, how often did you drive a vehicle in the last 12 months?	-1 = I prefer not to respond, 1 = Never, 6 = Every day
KmYear	Q5	About how many kilometres (miles) did you drive in the last 12 months?	-1 = I prefer not to respond, 1 = 0, 2 = 1-1000, …, 10 = more than 100,000
NrAcc	Q6	How many accidents were you involved in when driving a car in the last 3 years? (please include all accidents, regardless of	-1 = I prefer not to respond, 1 = 0, 7 = More than 5

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		how they were caused, how slight they were, or where they happened)?	
Vangered	Q7	How often do you do the following?: Becoming angered by a particular type of driver, and indicate your hostility by whatever means you can.	-1 = I prefer not to respond, 1 = 0 times per month, 2 = 1 to 3 times per month, …, 5 = 10 or more times per month
Vmotorway	Q8	How often do you do the following?: Disregarding the speed limit on a motorway.	-1 = I prefer not to respond, 1 = 0 times per month, 2 = 1 to 3 times per month, …, 5 = 10 or more times per month
Vresident	Q9	How often do you do the following?: Disregarding the speed limit on a residential road.	-1 = I prefer not to respond, 1 = 0 times per month, 2 = 1 to 3 times per month, …, 5 = 10 or more times per month
Vfollowing	Q10	How often do you do the following?: Driving so close to the car in front that it would be difficult to stop in an emergency.	-1 = I prefer not to respond, 1 = 0 times per month, 2 = 1 to 3 times per month, …, 5 = 10 or more times per month
Vrace	Q11	How often do you do the following?: Racing away from traffic lights with the intention of beating the driver next to you.	-1 = I prefer not to respond, 1 = 0 times per month, 2 = 1 to 3 times per month, …, 5 = 10 or more times per month
Vhorn	Q12	How often do you do the following?: Sounding your horn to indicate your annoyance with another road user.	-1 = I prefer not to respond, 1 = 0 times per month, 2 = 1 to 3 times per month, …, 5 = 10 or more times per month
Vphone	Q13	How often do you do the following?: Using a mobile phone without a hands free kit.	-1 = I prefer not to respond, 1 = 0 times per month, 2 = 1 to 3 times per month, …, 5 = 10 or more times per month
Vmean	N/A	Mean for Q7-12	Numeric value
PApast	Q14	In the past month, did you drive a car with a parking assistant?	-1 = I prefer not to respond, 1 = I do not know, 2 = No, 3 = Yes
PAhelp	Q15	A parking assistant is helpful.	-1 = I prefer not to respond, 1 = Disagree strongly, 5 = Agree strongly; 'I prefer not to respond'
PAannoy	Q16	A parking assistant is annoying.	-1 = I prefer not to respond, 1 = Disagree strongly, 5 = Agree strongly
PAopin	Q17	What do you think are the disadvantages of a parking assistant?	Textual response
PAfut	Q18	I would like to have a system in my car that	-1 = I prefer not to respond, 1 =

		can park the car automatically, just by pressing a button.	Disagree strongly, 5 = Agree strongly
FCWSpast	Q19	In the past month, did you drive a car with a forward collision warning system?	-1 = I prefer not to respond, 1 = I do not know, 2 = No, 3 = Yes
FCWShelp	Q20	A forward collision warning system is helpful.	-1 = I prefer not to respond, 1 = Disagree strongly, 5 = Agree strongly
FCWSannoy	Q21	A forward collision warning system is annoying.	-1 = I prefer not to respond, 1 = Disagree strongly, 5 = Agree strongly
FCWSfut	Q22	I would you like to have a system in my car that brakes automatically to avoid collisions (Autonomous Emergency Braking).	-1 = I prefer not to respond, 1 = Disagree strongly, 5 = Agree strongly
FCWSopin	Q23	What do you think are the disadvantages of a forward collision warning system?	Textual response
FSannoy	Q24	I believe that this type of surround sound system would be annoying.	-1 = I prefer not to respond, 1 = Disagree strongly, 5 = Agree strongly
FSfut	Q25	I would prefer to use such a sound system instead of opening the window, when driving through a scenic place (for example, a national park).	-1 = I prefer not to respond, 1 = Disagree strongly, 5 = Agree strongly
FSopin	Q26	What would be the advantages and the disadvantages of such sound system?	Textual response
TORint	Q27	Now imagine again that you are driving in an automated car (that can perform certain tasks without any interaction from the humans in the car). However, the automation cannot handle all possible situations, and you sometimes have to take over control. What type of warning signal would you like to receive in case manual take over is required?	1 = Warning sound: one beep, 2 = Warning sound: two beeps, 3 = Warning sound: horn sound, 4 = Warning sound: bell sound, 5 = Warning light, 6 = Visual warning message projected on windscreen 'Take over please', 7 = Vibrations in your seat, 8 = Vibrations in your steering wheel, 9 = Vibrations in your seatbelt, 10 = Vibrations in the floor, 11 = Female voice: 'Take over please', 12 = Male voice: 'Take over please', 13 = Other, 14 = None of the above
TORintot	Q28	If you answered 'Other' in the previous question, please specify what type of warning signal you would like to receive in the described scenario.	Textual response
FACpref	Q29	I would prefer to drive in a fully automated car rather than a normal (non automated) car.	-1 = I prefer not to respond, 1 = Disagree strongly, 5 = Agree

			strongly
YearAuto	Q30	In which year do you think that most cars will be able to drive fully automatically in your country of residence?	Year
Comm	Q31	Please provide any suggestions which could help engineers to build safe and enjoyable automated cars.	Textual response
SurvTime		Survey time (*taken from results generated by Crowdflower*)	Seconds

Configuration of CrowdFlower

In the instructions, the respondents were informed that they would need approximately 10 min to complete the survey. The task expiration time was set at 30 min. Contributors from all countries were allowed to participate in the survey in order to collect data from an as large and diverse population as possible. Moreover, the lowest level of experience of contributors 'Level 1 contributors' was selected. This level of experience accounts for 60% of completed work on CrowdFlower. As a result, the survey was available to a large number of workers, which allowed reaching a diverse group of users of the platform. Completing the survey more than once from the same IP address was allowed (note, however, that responses from multiple IP addresses were filtered out in our analyses). For the completion of the survey a payment of $0.15 was offered, and 2,000 responses were collected. The study was preceded by a pilot test with 10 participants.

Analyses

Descriptive statistics (i.e., means, medians, standard deviations, skewnesses, and numbers of responses) were calculated for each of the variables. The skewness was calculated as the third central moment divided by the cube of the standard deviation. A Spearman correlation matrix among the variables was created. The first author manually performed the analysis of textual responses (Q17, Q23, Q26, Q28, and Q31),

CrowdFlower automatically provides the respondent's country based on his/her IP address. We analysed the nationwide preferences of people from English-speaking (as defined by the UK government [75]: Antigua and Barbuda, Australia, Bahamas, Barbados, Belize, Canada, Dominica, Grenada, Ireland, Jamaica, New Zealand, Saint Lucia, Trinidad and Tobago, United Kingdom, and the United States) versus non-English speaking countries regarding the male versus female voice in supporting takeover requests during highly automated driving. Supplementary material contains the MATLAB script used to analyse the data.

Ethics Statement

All data were collected anonymously. The research was approved by the Human Research Ethics Committee (HREC) of the Delft University of Technology. Documented informed consent was obtained via a dedicated survey item asking whether the respondent had read and understood the survey instructions.

Results

Number of Respondents and Respondent Satisfaction

In total, 2,000 surveys were completed. The responses were gathered on 2 September 2014 between 15:00 and 20:15 (CET). The survey received an overall satisfaction rating of 4.4 out of 5.0. Additionally, the respondents ranked clearness of the instructions as 4.4 / 5.0, fairness of the questions as 4.2 / 5.0, easiness of the survey as 4.2 / 5.0, and the offered payment ($0.15 per respondent) as 4.1 / 5.0.

Data Filtering

The respondents who indicated they had not read the instructions (N = 10), who indicated they were under 18 and thereby did not adhere to the survey instructions (N = 6), who chose the *I prefer not to respond* or *I do not know* options in one or more of the multiple choice questions (N = 231), who indicated they never drive (N = 193), or who indicated they drive 0 km per year (N = 191) were excluded from the analyses. Since no limitations were applied on the number of responses that could be generated per IP address, some people completed the survey more than once. Such behaviour was seen as an indication that these persons participated in the survey primarily because of monetary gain. Thus, we applied a strict filter, and all data generated from non-unique IP address were removed (N = 465). In total, 795 surveys were removed, leaving 1,205 completed surveys for further analysis.

For the question “In which year do you think that most cars will be able to drive fully automatically in your country of residence?”, non-numeric responses (e.g., a year complemented by words such as “maybe 2030”, or “never”) and answers before the year 2014 were excluded, leaving 1,082 numeric responses.

Analyses at the Individual Level

The 1,205 respondents were from 91 countries (all 2,000 responses were associated with 95 countries). Descriptive statistics for all variables are listed in Table 2. The respondents took on average 9.2 minutes to complete the survey (SD = 5.6 min, median = 7.7 min). Supplementary material contains the entire correlation matrix. The correlations between variables that relate to questions about the PA, FCWS, and FS (PApast, PAhelp, PAannoy, PAfut, FCWSpast, FCWShelp, FCWSannoy, FCWSfut, FSannoy, and FSfut) on the one hand, and Age, DriveFreq, KmYear, NrAcc, the DBQ variables (Vangered, Vmotorway, Vresident, Vfollowing, Vrace, Vhorn, Vphone), YearAuto, and SurvTime, on the other, were overall small, between -0.15 and 0.25.

Table 2. Descriptive statistics for respondents

	Mean	Median	SD	Skewness	Min	Max
Gender	1.75	2	0.43	-1.17	1	2
Age	31.94	30	10.49	1.04	18	73
DriveFreq	4.72	5	1.21	-0.66	2	6
KmYear	4.09	4	1.78	0.92	2	10
NrAcc	1.47	1	0.94	2.88	1	7

Vangered	1.86	2	0.86	1.46	1	5
Vmotorway	1.85	2	1.05	1.54	1	5
Vresident	1.70	1	1.01	1.79	1	5
Vfollowing	1.45	1	0.77	2.07	1	5
Vrace	1.32	1	0.69	2.62	1	5
Vhorn	1.86	2	1	1.41	1	5
Vphone	1.64	1	1.01	1.84	1	5
Vmean	1.67	1.57	0.57	1.36	1	4.71
PApast	2.25	2	0.47	0.71	1	3
PAhelp	4.33	5	0.88	-1.38	1	5
PAannoy	2.35	2	1.18	0.39	1	5
PAfut	3.87	4	1.24	-0.93	1	5
FCWSpast	2.08	2	0.34	1.23	1	3
FCWShelp	4.11	4	1.04	-1.14	1	5
FCWSannoy	2.56	3	1.26	0.27	1	5
FCWSfut	3.77	4	1.22	-0.80	1	5
FSannoy	3.21	3	1.22	-0.18	1	5
FSfut	3	3	1.29	-0.09	1	5
FACpref	3.01	3	1.33	-0.05	1	5
YearAuto	2078.33	2030	713.77	30.73	2014	25000
SurvTime	553.95	462	338.41	1.34	58	1810

The respondents' mean and median age were 31.9 and 30 years, respectively. Figure 2 shows the distribution of the participants in 5-year wide age groups. 75.2% of the respondents were male (906 men vs. 299 women). The frequencies of the answers are provided in Table 3.

Table 3. Frequencies of answers

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Gender	299	906								
DriveFreq		79	108	293	313	412				
KmYear		250	245	337	148	76	77	49	16	7
NrAcc	855	226	79	19	13	6	7			
Vangered	417	629	96	33	30					
Vmotorway	541	466	97	39	62					
Vresident	663	379	78	32	53					
Vfollowing	807	295	70	20	13					
Vrace	939	182	60	15	9					
Vhorn	513	480	123	44	45					
Vphone	730	304	89	34	48					
PApast	909	247	48	1						
PAhelp	17	865	323							

PAannoy	14	39	134	367	651
PAfut	383	297	290	196	39
FCWSpast	86	109	175	338	497
FCWShelp	28	1058	119		
FCWSannoy	34	68	178	373	552
FCWSfut	331	254	324	208	88
FSannoy	82	123	203	377	420
FSfut	126	218	346	309	206
FACpref	204	222	312	301	166

Figure 3 shows that the participants expected most cars to be able to drive in fully automated mode in their countries of residence around 2030 (median response), with a highly skewed distribution.

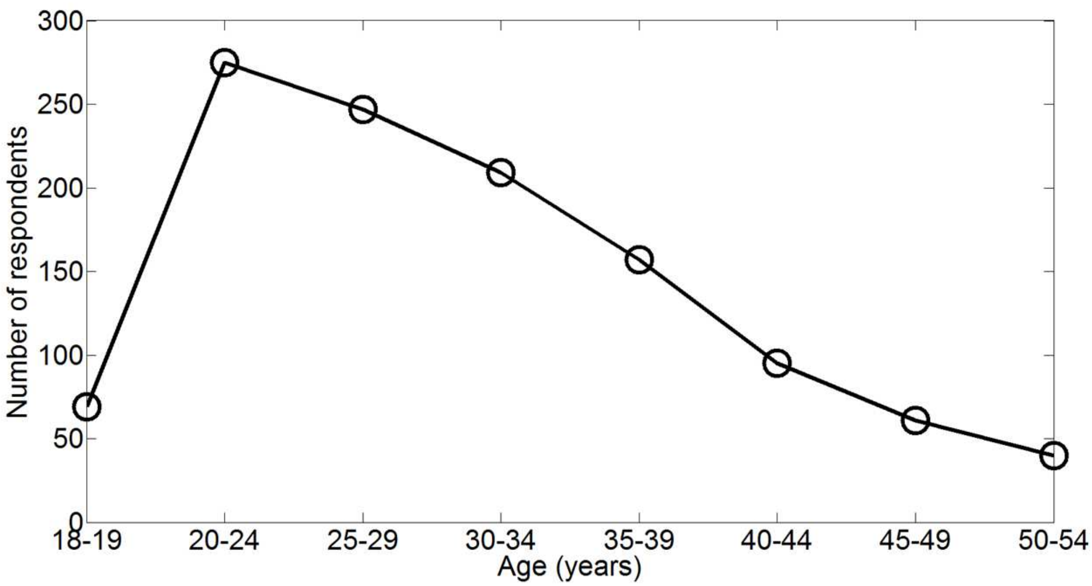


Figure 2. Distribution of age of participants aged between 18 and 54 years old who contributed to the survey.

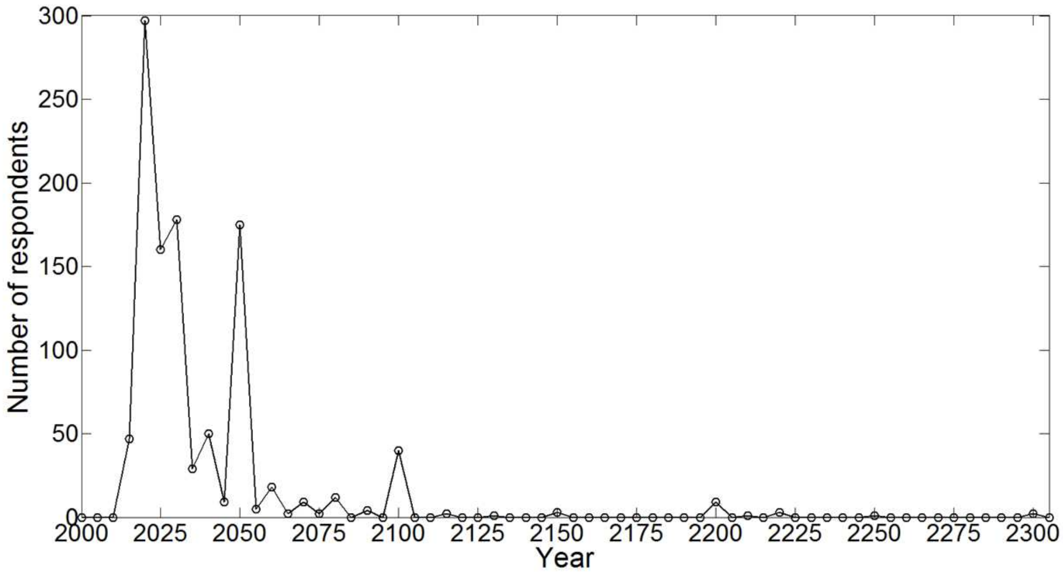


Figure 3. Numbers of respondents for the question: "*In which year do you think that most cars will be able to drive fully automatically on the roads in* your *country?*" (Q30). Years were divided into 5-year-wide bins.

The respondents were asked to provide their opinion on two characteristics of the PA and FCWS systems, annoyance and helpfulness, and they were asked whether they would be willing to have such systems in their own cars (Q18 for the PA and Q22 for the FCWS), all questions on a scale from *disagree strongly* to *agree strongly*. Figure 4 shows the results received from these questions.

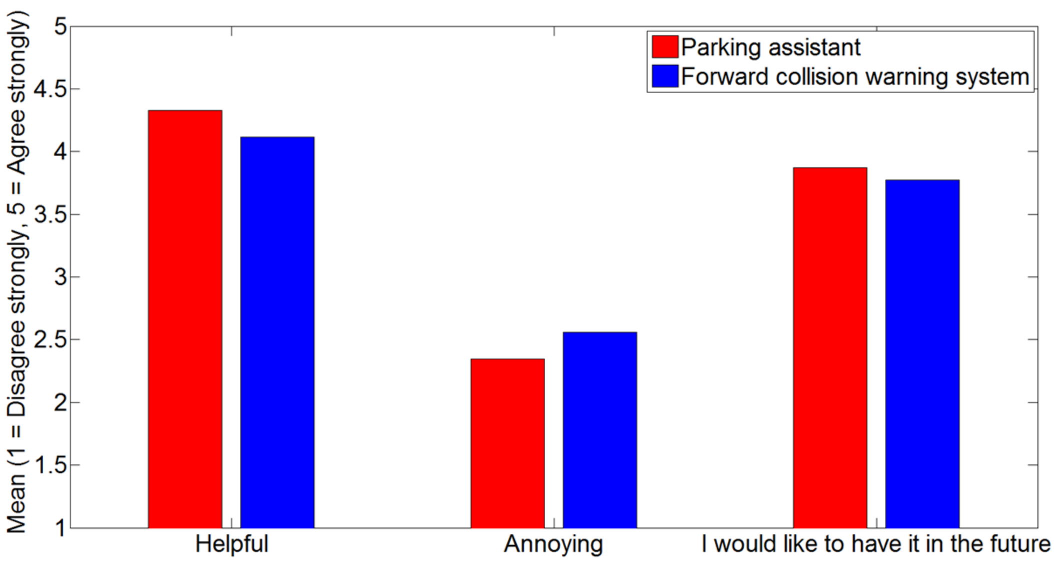
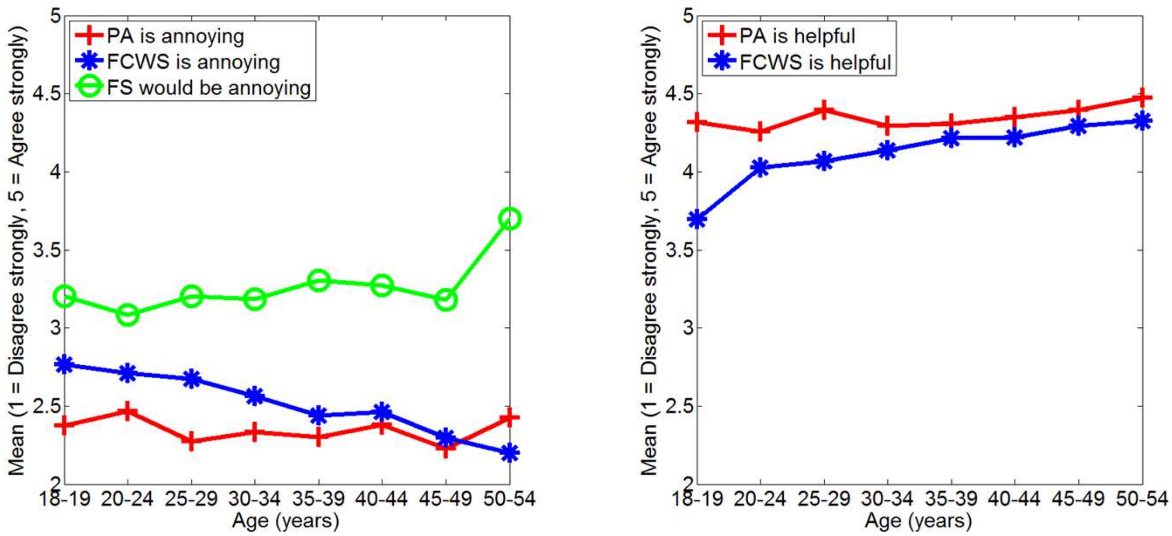


Figure 4. Opinion of respondents on whether a parking assistant (PA) and forward collision warning system (FCWS) are helpful (Q15 and Q20, respectively) and annoying (Q16 and Q21, respectively), and whether they would like to have such systems in their cars in the future (Q18 and Q22, respectively).

Figure 5 shows associations between the opinion of the respondents on annoyance and helpfulness of the PA and FCWS and their age divided into 5-year wide bins. Figure 5a shows that younger respondents found that both the PA (ρ = -0.05) and the FCWS (ρ = -0.14) were more annoying, although these effects were weak. The Spearman correlation between age and the respondents' annoyance of the FS was weak as well (ρ = 0.06). Figure 5b shows that the perceived helpfulness of the FCWS (ρ = 0.12) slightly increased with age. People who found the PA annoying, mostly indicated that the FCWS was also annoying (ρ = 0.47), and respondents who thought that the PA was helpful, considered the FCWS to be helpful as well (ρ = 0.34).



a) b)

Figure 5. a) Opinion on the annoyance of the parking assistant (PA, Q16), forward collision warning system (FCWS, Q21), and future system (FS, Q24) as a function of age. b) Opinion on the helpfulness of the PA (Q15) and FCWS (Q20) as a function of age. Age was divided into 5-year-wide bins.

Figure 6 shows the respondents' opinion on the proposed future system. The respondents were asked whether they would find such system annoying (Q24) and whether they would prefer to use such system instead of opening windows while driving in a fully automated car through a scenic place (Q25). A large portion of the respondents was neutral in their responses: 346 people choose option *Neither agree nor disagree* in Q24 and 312 persons chose the same option in Q25.

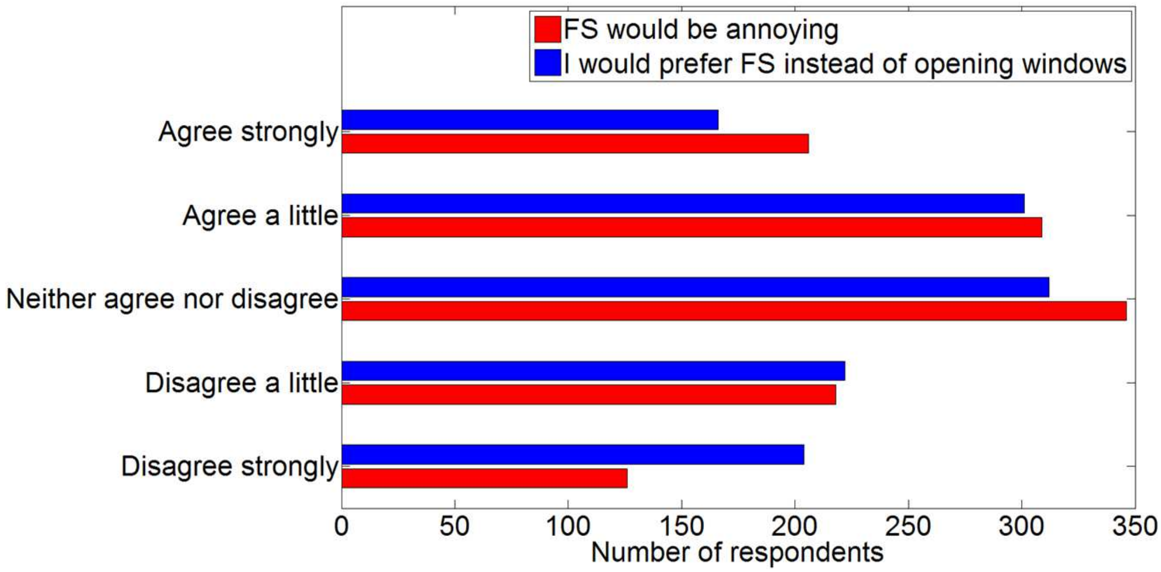


Figure 6. Distribution of opinions on whether the proposed future system (FS) would be annoying (Q24) and whether the respondents would prefer the system to opening windows in fully automated cars (Q25).

In Q27 the respondents were asked to report on the types of displays that they would like to be supported by in case of a takeover request during highly automated driving. The participants were allowed to select multiple options. Figure 7 shows that a large number of people preferred auditory feedback represented as a female voice saying 'Take over please' (N = 514). The number of respondents who chose the option with the male voice was considerably lower (N = 244). Figure 7 makes a distinction between the numbers of female and male respondents. It is apparent that both females and males prefer the female voice to hearing the same phrase produced by a male.

Other types of auditory feedback were reported as desired in the situation of a takeover request in the following order: two beeps (N = 375), one beep (N = 195), a bell sound (N = 194), and a horn sound (N = 135). The respondents indicated a high level of support for both visual signals offered in the question: a warning message projected on the windscreen 'Take over please' (N = 429) and a warning light (N = 406). However, participants showed a relatively low level of acceptance of the offered variations of a vibration interface: vibrations in the seat (N = 341), vibrations in the steering wheel (N = 179), vibrations in the seatbelt (N = 117), and vibrations in the floor (N = 64). Furthermore, the results seem to suggest that women are more likely to prefer a male voice, but are less likely to prefer a female voice.

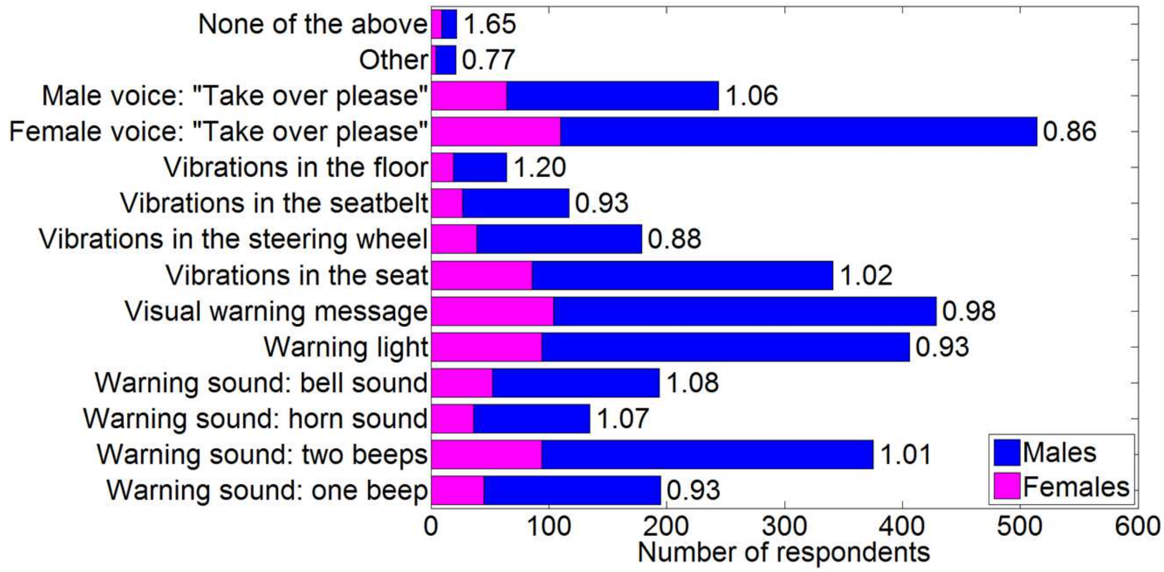


Figure 7. Numbers of respondents who indicated a preference for a particular takeover request during highly automated driving in the question: "*Now imagine again that you are driving in an automated car (that can perform certain tasks without any interaction from the humans in the car). However, the automation cannot handle all possible situations, and you sometimes have to take over control. What type of warning signal would you like to receive in case manual take over is required?"* (Q27). Each bar is supplemented by the corresponding 'risk ratios' of female respondents. That is, if the proportion of females exceeds 24.8% (= 299/(299+906)), the risk ratio is greater than 1, meaning that females are overrepresented. Conversely, if the proportion of females is less than 24.8%, the risk ratio is less than one, meaning that females are underrepresented.

Figure 8 shows the opinion of the respondents on the combinations of warning signals. The figure shows that most people (N = 188) prefer a sound signal (i.e., one or two beeps, a horn, or bell) without additional information. A large number of people indicated that they would benefit from being aided by a combination of all four modalities (N = 170) as well as by the combination of a sound signal, a visual message, and a voice (N = 101).

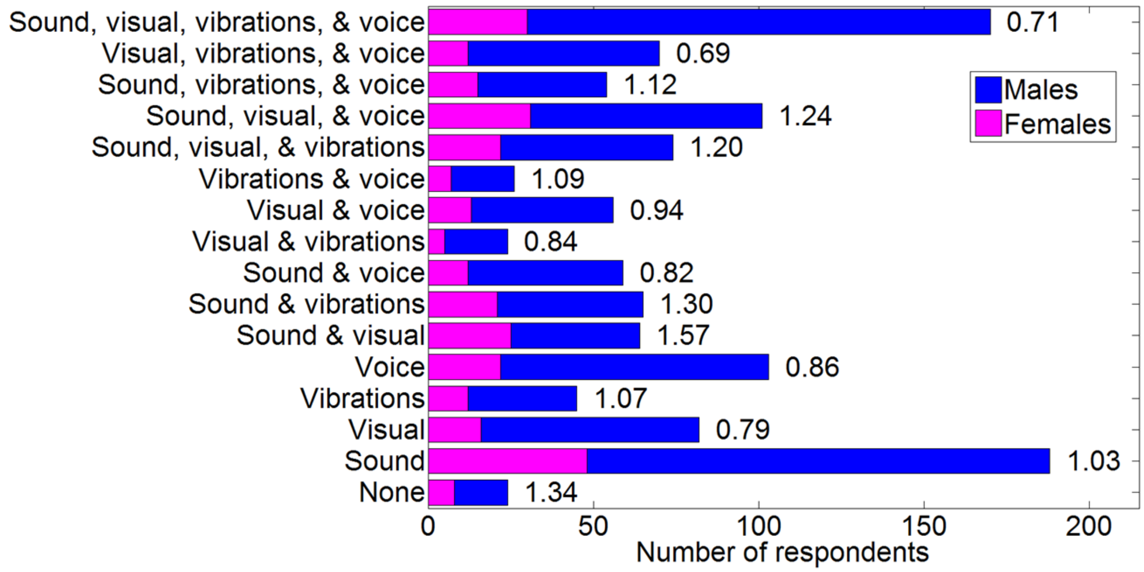


Figure 8. Preference to combinations of types of signals for aiding takeover requests during highly automated driving (Q27). Each bar is supplemented by the corresponding 'risk ratios' of female respondents. That is, if the proportion of females exceeds 24.8% (= 299/(299+906)), the risk ratio is greater than 1, meaning that females are overrepresented. Conversely, if the proportion of females is less than 24.8%, the risk ratio is less than one, meaning that females are underrepresented. All possible combinations are listed. Hence, the total number of respondents adds up to 1,205

Cross-National Differences in Opinion for Feedback for Takeover Requests

Next, we tested the hypothesis whether peoples' preference of female and male voice in supporting takeover requests in highly automated driving was different between English and non-English speaking countries. Figure 9 presents a scatter plot, showing the numbers of people from English- and non-English speaking countries who indicated that they would like to be guided by the female or male voice. The overall ratio between the number of people who expressed their preference to the female voice (N = 514) and the male voice (N = 244) was 2.11; the corresponding ratio between the female voice (N = 71) and the male voice (N = 37) for the respondents from English speaking countries was 1.92; and the ratio between the preference to the female voice (N = 443) and the male voice (N = 207) for the participants from non-English speaking countries was 2.14.

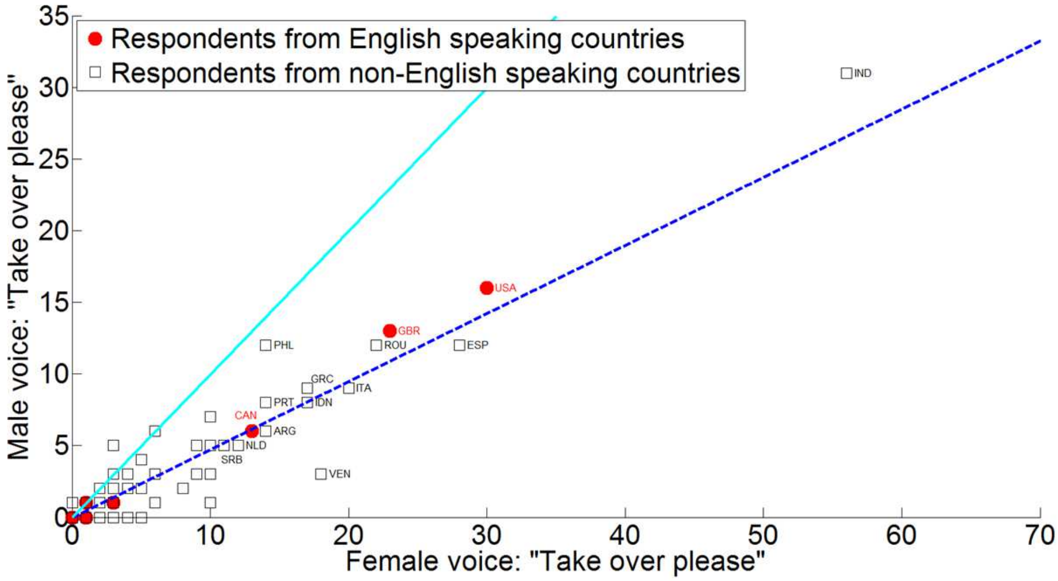


Figure 9. Numbers of respondents from English- and non-English speaking countries who indicated a preference for the male and female voices for a particular takeover request during highly automated driving in the question (Q27). The dotted line represents the ratio between the number of respondents who preferred the female voice and the number of respondents who preferred the male voice. The solid line is the line of unity. No labels for non-English speaking countries with fewer than five respondents were shown, to support the clarity of the figure. Country abbreviations are listed according to ISO 3166-1 alpha-3.

Analyses of Textual Comments

The respondents provided their feedback on the disadvantages of the PA in Q17. The responses that were less than five characters long (*N* = 181) or that were not written in English (*N* = 39) were ignored. In total, 1,213 comments gathered before data filtering were processed. 12.4% of the respondents (*N* = 151) provided negative feedback on the auditory interfaces in parking assistants. Many people (*N* = 135) indicated that the PA systems that they had used were annoying, for example: "*Sound should not be too loud and annoying*" and *"I think it could be annoying especially when your focusing"*. A number of respondents pointed out that the PA used overly loud sounds (*N* = 37). Next, a selection of answers to the question contained comments that the PA sounds are distracting (*N* = 21) and inaccurate (*N* = 48). A few respondents (*N* = 5) indicated that they would prefer other types of modalities, for example: "*annoying, use something else instead of the constant loud beeping sounds"* and *"The sound, a voice message would be better"*. A number of respondents (*N* = 5) indicated that the PA systems cannot be used by deaf people.

The participants indicated their opinion on the disadvantages of the FCWS in Q23. The responses that were less than five characters long (*N* = 276) or that were not written in English (*N* = 35) were not included in the analysis. A few responses (*N* = 16) indicated that they were not satisfied with the auditory feedback used in FCWS, for example: "*This situation might come up too often so the warning sound may get annoying fast*" and "*The beeps might feel annoying*".

Next, the respondents were asked to comment on possible advantages and disadvantages of the FS in Q26. The respondents that were less than five characters long (*N* = 138) or that were not written in

English (*N* = 46) were not included in the analysis. In total, 1,249 comments were analysed. A collection of mixed responses was received. Overall, more comments were classified as positive (*N* = 132) than negative (*N* = 52) to the FS. However, the respondents also pointed out their concerns about a number of characteristics that they associated with the system: annoyance to both a driver and to other participants in the traffic (*N* = 101), distraction (*N* = 47), and loudness (*N* = 28). A small group of respondents (*N* = 25) expressed their concerns that the system would be impractical; however, most of such concerns could be associated with the lack of understanding of the concept of a fully automated car. Certain respondents showed a high level of negativity caused by the lack of full understanding of the idea of the ability to filter only specific sounds coming from the outside environment, for example: "*You can not hear some bells or signal from other cars"* and *"Main disadvantage: makes driver unaware of any dangers"*. A few respondents may not have been able to visualize a fully automated car where a driver does not have to be alert of the outside environment, and expressed concerns about the inability to hear sounds coming from sources of danger such as other participants in traffic, for example: "*If car noises are filtered out how would you hear if another car is incoming*" and "*I feel that filtering other car noise may be dangerous*".

Lastly, in Q27 the respondents were asked to give their preference for types of interfaces for supporting a proposed situation that is common in highly automated driving – takeover requests. One of the options in that question was "*Other*", if the respondents chose this option, they were asked to provide further comments in Q28. The respondents that were less than five characters long (*N* = 32) or that were not written in English (*N* = 1) were ignored. In total, 22 responses were analysed. One person indicated that he/she would prefer to be aided by continuous beeps until he/she reclaimed control. Another response stated "*steering wheel up or down motion to signal steering wheel usage needed, accompanied by a specific message*". Another respondent mentioned that interfaces used in such scenario need to be adaptive depending on the urgency of the request "*It honestly depends on the situation the car needs me to take over for. Does it affect anyone's safety at all? Does it actually /need/ to be done straight away? Is it critically important in any other way? In those cases I'd obviously like a very noticeable signal however 'annoying' it may be. In other situations however I'd prefer a decent text message or a gentle reminder"*.

Discussion

The aim of this study was to obtain opinions on auditory interfaces in automated driving from a large number of people coming from all sides of the globe. The respondents that participated in the study were presented with two existing systems used in modern vehicles and one hypothetical setup envisioned for FAD. Our survey helped us to gather opinions from people before such technology is actually available.

Previous research suggests that the modality of aiding systems in automated cars should be chosen carefully to avoid frustration of people who will be using such vehicles and to increase safety of automation on public roads. Stanton, Young, McCaulder [69] expressed concerns that interfaces currently employed in ACC do not support the understanding of the behaviour and limitations of the system. A driving simulator study by Adell, Varhelyi, Fontana, and Bruel (2008) provided a comprehensive analysis of combinations of interfaces for supporting machine-aided safe driving. Participants in this study were most positive about the haptic interface, while the auditory warning signals were not appreciated by the participants, which may be explained by the nature of the experiment that exposed the participants to a high urgency scenario of avoiding rear-end collisions

[76]. Previous findings from the domain of aerospace show that the higher pitch of the female voice is preferred in noisy environments, which FAD or HAD may also be [77,78]. It has been argued that the effects reported in the two aforementioned studies may have been caused by the fact that these studies were performed in a predominantly male environment, and that the female voice is seen as overall more pleasant for most people, both for females and males [79]. There is some evidence that in cases of navigation systems and computer-generated speech, males may prefer the male voice [80,81], which suggests that the preference for the female versus male voice in auditory interfaces depends on the particular task under investigation. In the present research, respondents were asked to select the types of interfaces they are willing to be guided by during a takeover request. Results indicated that most participants preferred the female voice. The results of our survey further showed that the female voice is preferred in both English and non-English speaking countries. Thus, our findings reinforce the idea that the overall most preferred way to support the transition of control is an auditory instruction performed with a female voice.

It was found that the participants showed a relatively low level of appreciation of vibratory interfaces. This could be due to the fact that only a small number of systems that feature vibratory feedback are available in modern vehicles [82–86]. A relatively high number of people indicated that they would like to be aided by all four proposed modalities. Also, a large number of respondents indicated that the combination of a sound signal, a visual message, and a vibration signal would be preferable during takeover requests in highly automated vehicles. This is a surprising finding as such a combination is not common in current cars. A possible explanation of this finding could be that the respondents misinterpreted the question and instead of indicating their preference for a single modality/multimodal feedback, expressed their preferences for the kinds of interfaces that can be used separately from each other during takeover requests in highly automated driving.

The respondents indicated that they did not perceive the PA and the FCWS as annoying. At the same time, the respondents were not optimistic about the concept of the FS. The existing systems – the PA and FCWS – were more highly accepted, which may not be surprising, since these systems have already been tested and are already available on the market. The proposed FS was not highly rated either, possibly because the concept was perceived as a bad idea or because people could not envision it.

Small effects of age on the acceptance of FAD were previously reported in [87]. In the present study, we also observed small age effects regarding the self-reported annoyance of the three proposed systems: younger participants saw the PA and FCWS as more annoying than older respondents did. However, young respondents perceived the FS as less annoying that the older contributors. It is known that younger people are more likely to accept new technologies [88], and thus may be more successful at envisioning such abstract concepts as the FS. A somewhat stronger age effect was observed regarding the helpfulness of the PA and FCWS: older respondents found both systems more helpful than the younger participants. It is known that young people feel more confident behind the wheel of a car [89–91] and think that less external help is required [92], which may explain why young drivers are over-involved in traffic accidents.

Before the initiation of the survey, it was assumed that the proposed future system would be seen as a way to enhance the enjoyment of driving a car through a scenic place. The results showed that the participants were rather sceptical about such alternative: the system was perceived as somewhat annoying, with a mean score of 3.21 to question Q24 on the scale from disagree strongly (1) to agree strongly (5). The FS was proposed as a hypothetical system for fully automated vehicles. It should be noted that a large proportion of respondents chose the middle option *Neither agree nor disagree* in Q14 – Q16, Q18 – Q22, Q24, and Q25 possibly indicating difficulties with understanding the concepts of the proposed systems [93–95].

CrowdFlower offers a platform that supports full anonymity of participants. This anonymity may have encouraged respondents to express their thoughts freely, without fearing of being judged by the organizers of the survey. All but the last free-response items required people to enter at least one character. A large number of respondents did not provide meaningful comments. However, a substantial portion of respondents provided valuable opinions, facilitating the understanding of what people think about not only the use of auditory interfaces in future highly and fully automated cars, but also about the concept of automated driving in general. Numerous respondents expressed their concerns about the qualities of current PA and FCWS systems. Some participants suggested that they want to be aided by visual and vibratory feedback in addition to auditory feedback. A number of people indicated the inaccessibility of the modern PA to deaf users. However, several existing PAs already provide visual feedback [7,55,56,60], making such limitation irrelevant. A group of the respondents was sceptical about the introduction of highly and fully automated vehicles, which may be related to general consumer scepticism about new technologies. Respondents expected that most cars would drive fully automatically by the year 2030 (median value), a result that matches findings in previously published research [73,96].

The total cost of the study performed by means of conducting a crowdsourced online-based survey was lower than what was offered by companies that conduct similar surveys with help of classic methods [72]. A group of people filled in the survey more than once, and we reasoned that their responses ought not to be trusted. Thus, we applied a strict filter, and removed all respondents who filled out the survey more than once. We also excluded all people who had one or more missing items. With appropriate data quality control mechanisms, crowdsourcing is known can be a powerful research tool [97–100]. Nonetheless, as with any self-report questionnaire, the validity of the results is limited to what people can imagine or retrieve from their memory. Furthermore, CrowdFlower respondents are not representative of the entire population of stakeholders of future HAD cars. It is likely that such vehicles will initially be purchased by wealthy people, and projects on CrowdFlower are completed mostly by underprivileged people [73].

The scientific community and the automotive industry may be able to use the information gathered in the present questionnaire for the development of future guiding systems, in particular future iterations of parking assistants and forward collision warning systems, as well as the design of human-machine interfaces for automated driving.

References

[1] European Commision, Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, 2011. http://ec.europa.eu/transport/themes/strategies/2011_white_paper_en.htm (accessed November 7, 2014).

[2] D. Howard, D. Dai, Public Perceptions of Self-driving Cars: The Case of Berkeley, California 2, in: Transp. Res. Board 93rd Annu. Meet., 2014.

[3] G. Gururaj, Road traffic deaths, injuries and disabilities in India: Current scenario, Natl. Med. J. India. 21 (2008) 14–20.

[4] World Health Organization, Global status report on road safety 2013, World Health Organization, 2013. http://www.who.int/violence_injury_prevention/road_safety_status/2013/en/ (accessed December 17, 2014).

[5] N.J. Goodall, Machine Ethics and Automated Vehicles, Road Veh. Autom. (2014).

[6] T. Gasser, D. Westhoff, BASt-study: Definitions of automation and legal issues in Germany, in: Present. Road Veh. Autom. Work., 2012.

[7] BMW, BMW ConnectedDrive from A to Z, (2013). http://www.bmw.com/com/en/insights/technology/connecteddrive/2013/a_to_z/index.html (accessed November 7, 2014).

[8] Volvo, Volvo Car Group reveals world-class safety and support features that will be introduced in the all-new XC9, (2013). https://www.media.volvocars.com/global/en-gb/media/pressreleases/49875/volvo-cars-reveals-world-class-safety-and-support-features-to-be-introduced-in-the-all-new-xc90-in-2 (accessed November 7, 2014).

[9] Daimler, DISTRONIC PLUS: Warns and assists the driver, (2013). http://www.daimler.com/dccom/0-5-1210218-1-1210321-1-0-0-1210228-0-0-135-0-0-0-0-0-0-0.html (accessed November 7, 2014).

[10] V.A. Banks, N.A. Stanton, Hands and Feet Free Driving: Ready or Not?, Adv. Hum. Asp. Transp. Part II. 8 (2014) 55.

[11] T.A. Dingus, M.C. Hulse, W. Barfield, Human-system interface issues in the design and use of advanced traveler information systems, Hum. Factors Intell. Transp. Syst. (1998) 359–395.

[12] E. Alicandri, J. Moyer, Human factors and the automated highway system, in: Proc. Hum. Factors Ergon. Soc. Annu. Meet., 1992: pp. 1064–1067.

[13] L. Levitan, G. Golembiewski, J.R. Bloomfield, Human factors issues for automated highway systems, Its J. 4 (1998) 21–47.

[14] N.A. Stanton, M.S. Young, G.H. Walker, H. Turner, S. Randle, Automating the driver’s control tasks, Int. J. Cogn. Ergon. 5 (2001) 221–236.

[15] C. Gold, D. Dambock, L. Lorenz, K. Bengler, “Take over!” How long does it take to get the driver back into the loop?, Proc. Hum. Factors Ergon. Soc. Annu. Meet. 57 (2013) 1938–1942. doi:10.1177/1541931213571433.

[16] D.A. Norman, The’problem'with automation: inappropriate feedback and interaction, not'over-automation', Philos. Trans. R. Soc. London. B, Biol. Sci. 327 (1990) 585–593.

[17] M. Weber, Where to? A History of Autonomous Vehicles, (2014). http://www.computerhistory.org/atchm/where-to-a-history-of-autonomous-vehicles/ (accessed December 27, 2014).

[18] J. Wetmore, Driving the Dream. The History and Motivations Behind 60 Years of Automated Highway Systems in America, Automot. Hist. Rev. (2003) 4–19. http://archive.cspo.org/documents/article_Wetmore-DrivingTheDream.pdf (accessed December 27, 2014).

[19] A.H. Jamson, N. Merat, O. Carsten, F.C.H. Lai, Fully-automated driving: the road to future vehicles, in: Proc. Sixth Int. Driv. Symp. Hum. Factors Driv. Assessment, Train. Veh. Des., 2011: pp. 2–9.

[20] P. Varaiya, Smart cars on smart roads. Problems of control, IEEE Trans. Automat. Contr. 38 (1993) 195–207. doi:10.1109/9.250509.

[21] C. Bergenhem, H. Pettersson, E. Coelingh, C. Englund, S. Shladover, S. Tsugawa, Overview of platooning systems, in: 19th ITS World Congr. Vienna, Austria, 2012: pp. 1–7. http://publications.lib.chalmers.se/publication/174621.

[22] J. Markoff, Google cars drive themselves, in traffic, New York Times. 10 (2010) A1.

[23] Continental, Continental Strategy Focuses on Automated Driving, (2012). https://www.conti-online.com/www/pressportal_com_en/themes/press_releases/1_topics/automated_driving_en/pr_2012_12_18_automated_driving_en.html (accessed November 8, 2014).

[24] S. Underwood, Automated Vehicles Forecast: Vehicle Symposium Opinion Survey, (2014).

[25] L. Gomes, Google self-driving car: It may never actually happen., Slate. (2014). http://www.slate.com/articles/technology/technology/2014/10/google_self_driving_car_it_may_never_actually_happen.html (accessed December 17, 2014).

[26] J. Yoshida, Fully Autonomous Car? Don't Buy Shotgun Yet, EE Times. (2014). http://www.eetimes.com/author.asp?section_id=36&doc_id=1322246 (accessed December 17, 2014).

[27] L. Nilsson, Safety effects of adaptive cruise controls in critical traffic situations, in: `Steps Forward'. Proc. Second World Congr. Intell. Transp. Syst. `95 Yokohama, 1995: pp. 1254 – 9.

[28] J. Nilsson, N. Strand, P. Falcone, J. Vinter, Driver performance in the presence of adaptive cruise control related failures: Implications for safety analysis and fault tolerance, in: Dependable Syst. Networks Work. (DSN-W), 2013 43rd Annu. IEEE/IFIP Conf., 2013: pp. 1–10.

[29] M. Ebbatson, The Loss of Manual Flying Skills in Pilots of Highly Automated Airliners, Cranfield University, 2009. https://dspace.lib.cranfield.ac.uk/handle/1826/3484 (accessed November 10, 2014).

[30] S.F. Scallen, P.A. Hancock, J.A. Duley, Pilot performance and preference for short cycles of automation in adaptive function allocation, Appl. Ergon. 26 (1995) 397–403. doi:10.1016/0003-6870(95)00054-2.

[31] J.C.F. De Winter, R. Happee, M.H. Martens, N.A. Stanton, Effects of adaptive cruise control and highly automated driving on workload and situation awareness: A review of the empirical evidence, Transp. Res. Part F Traffic Psychol. Behav. 27 (2014) 196–217. doi:10.1016/j.trf.2014.06.016.

[32] D. Heikoon, J.C.F. De Winter, B. Van Arem, N.A. Stanton, Psychological constructs in driving automation: A consensus model and critical comment on construct proliferation, 2015.

[33] C.D. Wickens, J.G. Hollands, Engineering Psychology and Human Performance, 4th ed., 2013. doi:10.1146/annurev.ps.27.020176.001513.

[34] S. Holland, D.R. Morse, H. Gedenryd, AudioGPS: Spatial audio navigation with a minimal attention interface, Pers. Ubiquitous Comput. 6 (2002) 253–259. doi:10.1007/s007790200025.

[35] D.R. Begault, Head-up auditory displays for traffic collision avoidance system advisories: A preliminary investigation, Hum. Factors J. Hum. Factors Ergon. Soc. 35 (1993) 707–717.

[36] A.W. Bronkhorst, J.A. Veltman, L. van Breda, Application of a three-dimensional auditory display in a flight task., 1996. doi:10.1518/001872096778940859.

[37] C. Ho, N. Reed, C. Spence, Multisensory in-car warning signals for collision avoidance, Hum. Factors J. Hum. Factors Ergon. Soc. 49 (2007) 1107–1114.

[38] A. Barón, P. Green, Safety and usability of speech interfaces for in-vehicle tasks while driving: A brief literature review, 2006.
[39] N.A. Stanton, J. Edworthy, Human factors in auditory warnings, Ashgate, 1999.
[40] J. Engström, E. Johansson, J. Östlund, Effects of visual and cognitive load in real and simulated motorway driving, Transp. Res. Part F Traffic Psychol. Behav. 8 (2005) 97–120. doi:10.1016/j.trf.2005.04.012.
[41] M.A. Recarte, L.M. Nunes, Effects of verbal and spatial-imagery tasks on eye fixations while driving., J. Exp. Psychol. Appl. 6 (2000) 31–43. doi:10.1037/1076-898X.6.1.31.
[42] E.D. Mynatt, Auditory Presentation of Graphical User Interfaces, Interface. (1990).
[43] S.M. Belz, G.S. Robinson, J.G. Casali, A new class of auditory warning signals for complex systems: auditory icons., 1999. doi:10.1518/001872099779656734.
[44] C. Nass, C. Yen, The Man Who Lied to His Laptop: What We Can Learn About Ourselves from Our Machines, Penguin Group US, 2010. http://books.google.com/books?hl=en&lr=&id=w4TIN88bSCIC&pgis=1 (accessed November 6, 2014).
[45] L. Takayama, C. Nass, Driver safety and information from afar: An experimental driving simulator study of wireless vs. in-car information services, Int. J. Hum. Comput. Stud. 66 (2008) 173–184. doi:10.1016/j.ijhcs.2006.06.005.
[46] B. Bosker, Why Siri's Voice Is Now A Man (And A Woman), Huffingt. Post. (2013). http://www.huffingtonpost.com/2013/06/11/siri-voice-man-woman_n_3423245.html (accessed December 18, 2014).
[47] I.-M. Jonsson, N. Dahlbäck, I Can't Hear You? Drivers Interacting with Male or Female Voices in Native or Non-native Language, in: C. Stephanidis (Ed.), Univers. Access Human-Computer Interact. Context Divers. SE - 33, Springer Berlin Heidelberg, 2011: pp. 298–305. doi:10.1007/978-3-642-21666-4_33.
[48] AOL, New Cars with Parking Assist, (2014). http://autos.aol.com/car-finder/option-parking+assist/ (accessed November 10, 2014).
[49] Volkswagen, Park assist, (2014). http://www.volkswagen.co.uk/technology/parking-and-manoeuvring/park-assist (accessed November 10, 2014).
[50] Toyota, Parking, (2014). http://www.toyota-global.com/innovation/safety_technology/safety_technology/parking/ (accessed November 10, 2014).
[51] BMW, BMW X5: Park Assistant, (2014). http://www.bmw.com/com/en/newvehicles/x/x5/2013/showroom/driver_assistance/park_assistant.html#t=l (accessed November 12, 2014).
[52] C. Kessler, A. Etemad, G. Alessandretti, K. Heinig, Selpi, R. Brouwer, et al., euroFOT - Final Report, Aachen, 2012. http://www.eurofot-ip.eu/download/library/deliverables/eurofotsp120121212v11dld113_final_report.pdf (accessed November 12, 2014).
[53] K. Kingsley, Evaluating crash avoidance countermeasures using data from FMCS's/NHTSA's large truck accident causation study, in: 21st Int. Tech. Conf. Enhanc. Saf. Veh. Conf., Stuttgart, Germany, 2009. http://www-nrd.nhtsa.dot.gov/pdf/esv/esv21/09-0460.pdf (accessed November 10, 2014).

[54] A.H. Jamson, F.C.H. Lai, O.M.J. Carsten, Potential benefits of an adaptive forward collision warning system, Transp. Res. Part C Emerg. Technol. 16 (2008) 471–484. doi:10.1016/j.trc.2007.09.003.
[55] Honda, Forward Collision Warning, (2014). http://owners.honda.com/vehicles/information/2014/Accord-Coupe/features/Forward-Collision-Warning/3 (accessed November 10, 2014).
[56] Volvo, One million cars with pioneering auto brake technology sold : Volvo Car Group reaches landmark safety milestone, (2013). http://www.volvocars.com/uk/top/about/news-events/pages/default.aspx?itemid=195 (accessed November 12, 2014).
[57] E. Dagan, O. Mano, G.P. Stein, A. Shashua, Forward collision warning with a single camera, IEEE Intell. Veh. Symp. 2004. (2004). doi:10.1109/IVS.2004.1336352.
[58] N. Srinivasa, Vision-based vehicle detection and tracking method for forward collision warning in automobiles, Intell. Veh. Symp. 2002. IEEE. 2 (2002). doi:10.1109/IVS.2002.1188021.
[59] Mercedes-Benz, Pre-Safe, (2014). http://www2.mercedes-benz.co.uk/content/unitedkingdom/mpc/mpc_unitedkingdom_website/en/home_mpc/passengercars/home/corporate_sales0/fleet/leasing/our_advantages/Safety.0009.html (accessed November 12, 2014).
[60] Ford, Collision warning with brake support, (2014). http://support.ford.com/maintenance/collision-warning-brake-support (accessed January 11, 2015).
[61] R. Miller, Q. Huang, An adaptive peer-to-peer collision warning system, in: Veh. Technol. Conf. 2002. VTC Spring 2002. IEEE 55th, 2002: pp. 317–321.
[62] A.H. Eichelberger, A.T. McCartt, Volvo drivers' experiences with advanced crash avoidance and related technologies., Traffic Inj. Prev. 15 (2014) 187–195. doi:10.1080/15389588.2013.798409.
[63] D. Dobler, M. Haller, P. Stampfl, ASR, in: ACM SIGGRAPH 2002 Conf. Abstr. Appl. - SIGGRAPH '02, ACM Press, New York, New York, USA, 2002: p. 148. doi:10.1145/1242073.1242161.
[64] J. Garas, Adaptive 3D sound systems, (2000). http://dl.acm.org/citation.cfm?id=358343 (accessed December 18, 2014).
[65] L. Godinho, J. António, A. Tadeu, 3D sound scattering by rigid barriers in the vicinity of tall buildings, Appl. Acoust. 62 (2001) 1229–1248. doi:10.1016/S0003-682X(01)00004-4.
[66] M. Lumbreras, J. Sánchez, M. Barcia, A 3D sound hypermedial system for the blind, in: Proc. First Eur. Conf. Disabil. Virtual Real. Assoc. Technol., 1996: pp. 187–191.
[67] J.M. Rozier, Hear&There: An augmented reality system of linked audio, Massachusetts Institute of Technology, 2000.
[68] B.D. Seppelt, J.D. Lee, Making adaptive cruise control (ACC) limits visible, Int. J. Hum. Comput. Stud. 65 (2007) 192–205. doi:10.1016/j.ijhcs.2006.10.001.
[69] N.A. Stanton, M. Young, B. McCaulder, Drive-by-wire: The case of driver workload and reclaiming control with adaptive cruise control, Saf. Sci. 27 (1997) 149–159. doi:10.1016/S0925-7535(97)00054-4.
[70] N.A. Stanton, M.S. Young, G.H. Walker, H. Turner, S. Randle, Automating the Driver's Control Tasks, Int. J. Cogn. Ergon. 5 (2001) 221–236. doi:10.1207/S15327566IJCE0503_5.

[71] F. Flemisch, A. Kaussner, I. Petermann, A. Schieben, N. Schöming, HAVE-IT. Highly automated vehicles for intelligent transport. Validation of concept on optimum task repartition (Deliverable D.33.6), Regensburg, Germany, 2011. http://www.haveit-eu.org/LH2Uploads/ItemsContent/24/HAVEit_212154_D33.6_Public.pdf (accessed December 18, 2014).

[72] J.C.F. De Winter, M. Kyriakidis, D. Dodou, R. Happee, Using CrowdFlower to study the relationship between self-reported violations and traffic accidents, in: AHFE, 2015.

[73] M. Kyriakidis, R. Happee, J.C.F. De Winter, Public Opinion on Automated Driving: Results of an International Questionnaire Among 5,000 Respondents, Soc. Sci. Res. Netw. (2014). http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2506579.

[74] J.C.F. De Winter, Predicting self-reported violations among novice license drivers using pre-license simulator measures, Accid. Anal. Prev. 52 (2013) 71–79. doi:10.1016/j.aap.2012.12.018.

[75] UK Visas & Immigration, Tier 4 of the Points Based System – Policy Guidance, (2014) 22. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/370866/T4_Guidance_11-14.pdf (accessed February 6, 2015).

[76] E. Adell, A. Varhelyi, M.D. Fontana, L. Bruel, Test of HMI Alternatives for Driver Support to Keep Safe Speed and Safe Distance - A Simulator Study, Open Transp. J. 2 (2008) 53–64. doi:10.2174/1874447800802010053.

[77] C.W. Nixon, L.J. Morris, A.R. McCavitt, R.L. McKinley, T.R. Anderson, M.P. McDaniel, et al., Female voice communications in high levels of aircraft cockpit noises--part I: spectra, levels, and microphones., Aviat. Space. Environ. Med. 69 (1998) 675–683.

[78] C. Nixon, T. Anderson, L. Morris, A. McCavitt, R. McKinley, D. Yeager, et al., Female voice communications in high level aircraft cockpit noises--part II: vocoder and automatic speech recognition systems., Aviat. Space. Environ. Med. 69 (1998) 1087–1094.

[79] B. Feiler, Turn right, my love, New York Times. 25 (2010).

[80] E.J. Lee, C. Nass, S. Brave, Can computer-generated speech have gender?, in: CHI ’00 Ext. Abstr. Hum. Factors Comput. Syst. - CHI '00, ACM Press, New York, New York, USA, 2000: p. 289. doi:10.1145/633292.633461.

[81] M. Aguilar, German drivers refuse directions for female voice GPS, CU Indep. (2010). http://cuindependent.com/2010/09/23/german-drivers-refuse-directions-for-female-voice-gps/18290 (accessed November 6, 2014).

[82] C.L. Baldwin, C. Spence, J.P. Bliss, J.C. Brill, M.S. Wogalter, C.B. Mayhorn, et al., Multimodal Cueing: The Relative Benefits of the Auditory, Visual, and Tactile Channels in Complex Environments, Proc. Hum. Factors Ergon. Soc. Annu. Meet. 56 (2012) 1431–1435. doi:10.1177/1071181312561404.

[83] C. Spence, C. Ho, Crossmodal information processing in driving, (2009).

[84] C.L. Baldwin, J.L. Eisert, A. Garcia, B. Lewis, S.M. Pratt, C. Gonzalez, Multimodal urgency coding: auditory, visual, and tactile parameters and their impact on perceived urgency., Work. 41 Suppl 1 (2012) 3586–91. doi:10.3233/WOR-2012-0669-3586.

[85] J.H. Hogema, S.C. De Vries, J.B.F. Van Erp, R.J. Kiefer, A Tactile Seat for Direction Coding in Car Driving: Field Evaluation, IEEE Trans. Haptics. 2 (2009) 181–188. doi:10.1109/TOH.2009.35.

[86] J.B.F. Van Erp, H.A.H.C. Van Veen, Vibrotactile in-vehicle navigation system, Transp. Res. Part F Traffic Psychol. Behav. 7 (2004) 247–256. doi:10.1016/j.trf.2004.09.003.

[87] W. Payre, J. Cestac, P. Delhomme, Intention to use a fully automated car: Attitudes and a priori acceptability, Transp. Res. Part F Traffic Psychol. Behav. (2014). doi:10.1016/j.trf.2014.04.009.
[88] M. Tacken, F. Marcellini, H. Mollenkopf, I. Ruoppila, Z. Széman, Use and acceptance of new technology by older people. Findings of the international MOBILATE survey: "Enhancing mobility in later life," Gerontechnology. 3 (2005). doi:10.4017/gt.2005.03.03.002.00.
[89] D.D. Clarke, P. Ward, W. Truman, Voluntary risk taking and skill deficits in young driver accidents in the UK., Accid. Anal. Prev. 37 (2005) 523–9. doi:10.1016/j.aap.2005.01.007.
[90] M.L. Matthews, A.R. Moran, Age differences in male drivers' perception of accident risk: The role of perceived driving ability, Accid. Anal. Prev. 18 (1986) 299–313. doi:10.1016/0001-4575(86)90044-8.
[91] A.H. Lee, M.R. Stevenson, K. Wang, K.K.W. Yau, Modeling young driver motor vehicle crashes: data with extra zeros, Accid. Anal. Prev. 34 (2002) 515–521. doi:10.1016/S0001-4575(01)00049-5.
[92] J.D. Lee, Technology and teen drivers, J. Safety Res. 38 (2007) 203–213. doi:10.1016/j.jsr.2007.02.008.
[93] J.T. Kulas, A.A. Stachowski, Middle category endorsement in odd-numbered Likert response scales: Associated item characteristics, cognitive demands, and preferred meanings, J. Res. Pers. 43 (2009) 489–493. doi:10.1016/j.jrp.2008.12.005.
[94] J.T. Kulas, A.A. Stachowski, B.A. Haynes, Middle response functioning in likert-responses to personality items, J. Bus. Psychol. 22 (2008) 251–259. doi:10.1007/s10869-008-9064-2.
[95] P. Sturgis, C. Roberts, P. Smith, Middle Alternatives Revisited: How the neither/nor Response Acts as a Way of Saying "I Don't Know"?, Sociol. Methods Res. 43 (2012) 15–38. doi:10.1177/0049124112452527.
[96] K. Sommer, Mobility Study 2013, 2013. http://www.continental-corporation.com/www/pressportal_com_en/general/ov_automated_driving_en/ov_mobility_study_en/ (accessed November 7, 2014).
[97] J. Howe, The rise of crowdsourcing, Wired Mag. 14 (2006) 1–4.
[98] A. Kittur, E.H. Chi, B. Suh, Crowdsourcing user studies with Mechanical Turk, in: Proc. SIGCHI Conf. Hum. Factors Comput. Syst., 2008: pp. 453–456.
[99] M.J.C. Crump, J. V. McDonnell, T.M. Gureckis, Evaluating Amazon's Mechanical Turk as a Tool for Experimental Behavioral Research, PLoS One. 8 (2013). doi:10.1371/journal.pone.0057410.
[100] W. Mason, S. Suri, Conducting behavioral research on Amazon's Mechanical Turk, Behav. Res. Methods. 44 (2012) 1–23. doi:10.3758/s13428-011-0124-6.