Contemporary Automotive Infotainment Solutions to Empower Front-Seat Passengers

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Automotive infotainment systems have neglected front-seat passengers’ needs as they have not been the primary users of the car. Recently R&D efforts in academia and the automotive industry have been directed towards empowering front-seat passengers. Front-seat passengers can spend substantial time in the car accompanying the driver, but without having sufficient means to entertain themselves. This paper first briefly introduces the (front-seat) passenger-oriented studies in automotive user experience (UX) literature and concept cars presented in several automotive or technology shows in 2015-2016. The identified solutions are then categorized based on the varied dimensions of the infotainment experience. This helps the understanding of diverse aspects of the innovations including: novelties in in-car interactions based on embodiment of interaction technologies; new functionalities/infotainment features; and hedonic or pragmatic contributions to the passenger experience. However, there is still a need to investigate the link between the dimensions of front-seat passenger experience to prevent the users being exposed to underexplored technology-driven designs.

front-seat passenger experience, automotive infotainment, automotive user interfaces, automotive UX trends

1 Introduction
Traditionally, automotive user interfaces have been designed within the limitations of ‘driving activity’, since drivers have been the main controllers of the vehicle. This has resulted in automobile interiors and infotainment systems which neglect the passenger experience. Nevertheless, passengers may spend as much time in the car being driven around but without having the means to entertain themselves. Within the shared experience of mobility, passengers have fewer distraction issues and they can concentrate on more varied stimuli. Their physical access to diverse parts of interior is also not as limited as that of the driver. These opportunities encouraged us to rethink the way passengers interact with the car infotainment system to empower them and to enrich their
travel experience. Empowering front-seat passengers means increasing their involvement in the car journeys by providing them means that will add both pragmatic and hedonic values to their travel experience.

This paper provides an analysis on the R&D efforts in academia and automotive industry within the scope of “automotive infotainment solutions empowering front-seat passengers”. It refers to passenger-oriented automotive UX studies and a detailed technology review of a selection of concept cars introduced at the Geneva Motor Show (2015-2016), Frankfurt Auto Show (2015), and Consumer Electronics Show (CES) (2015-2016).

It is important to mention that the introduction of autonomous driving enables drivers to act as front-seat passengers as well. To meet this challenge, automobile manufacturers have started to come up with interface solutions that will fill that gap created by the elimination of the driving task. This paper will refer to these solutions as part of passenger empowerment, although the distinction between the driver and front-seat passenger still continues even in autonomous car concepts since someone needs to take control of the car when autonomous driving option cannot be used.

2 Brief introduction to passenger-oriented studies in automotive UX literature

When we analyse (front-seat) passenger-oriented studies in automotive UX literature, there are two main approaches: i) emphasis on the driver and front-seat passenger collaboration and ii) emphasis on the front-seat passenger and investigation of what automotive user interfaces can offer them beyond enabling them to assist drivers in driving-related tasks.

2.1 i) Driver and front-seat passenger collaboration

The collaboration between driver and front-seat passenger is mainly handled through using the navigation system together. To exemplify, Perterer et al. (2015) introduce a tablet-based navigation app concept and prototype “Co-Navigator” that provides diverse kinds of information, such as landmarks and upcoming hazard warnings, then they discuss how front-seat passengers can make use of the app. Rümelin et al. (2013) also demonstrate a system to enable driver-passenger collaboration by letting front-seat passenger deal with secondary navigation-related tasks which are too much to handle for the drivers. The results of user-evaluations of this system show that the occupant (either the driver or the passenger) executing the defined task felt more involved; however, the level of control increased for both car occupants when the passenger provided support in the task.

Similar studies include “I need help! Exploring Collaboration in the Car” by Gridling et al. (2012) and “Where Should I Turn? Moving from Individual to Collaborative Navigation Strategies to Inform the Interaction Design of Future Navigation Systems” by Forlizzi et al. (2010). Another study called “Gaze Assist” by Trösterer et al. (2015) explore the eye-gaze detection as a new way sharing information between the front-seat passenger and the driver, since the sitting positions of these two front-seat occupants and driver’s need to keep the eye on the road do not allow them to have a natural face-to-face communication. To facilitate the communication and the collaboration, the system works in a way that the eye gaze of the front-seat passenger is captured and visualized for the driver to show exactly where the front-seat passenger looks. In this study they compare two different visualisation techniques (LEDs at the bottom of the windshield vs. dots on the screen) and reach to the conclusion that while the LED visualisations is better to avoid driver distraction, dots perform better in terms of visual accuracy and control of the front-seat passenger. The use cases for front-seat passenger’s “gaze assistance” are illustrated as warning the driver for upcoming hazards or giving support in navigating in an unfamiliar region (Trösterer et al., 2015).
2.2 ii) “Passengering” beyond driver-passenger collaboration

This category of research puts passengers as the focal point and analyse their needs and activities as passengers. In this regard, Inbar and Tractinsky (2011) propose that IVIS (Inter-vehicle information system) should be made more accessible to passengers so we can reduce boredom and increase a sense of inclusion of the front or rear-seat passengers. They also argue that making in-car information more accessible to passengers can eliminate the need for the driver to share trip-related information with passengers, which reduces distraction and information load of drivers. In addition, Lee et al. (2015) present a study on a split-view navigation system and list the information needed or prioritized by the driver and front-seat passenger individually during the phases of the journey.

The examples included thus far relate to the shared use of the available in-car information with passengers. Nevertheless, there are also academic efforts to understand (front-seat) passengers’ further needs and interests beyond the provision of travel information alone. Osswald et al. (2013) presents a probing study conducted with front-seat passengers. They demonstrate a cluster of the modalities (e.g. interface modalities, radio, display); services (e.g. navigation, internet, social media, games); context (e.g. weather, speed, front-seat passenger area) and information (e.g. surroundings, TV, distance left/travelled) the front-passengers deal with or mention about the most.

3 Analysis of (front-seat) passenger-oriented infotainment solutions

We have briefly introduced the approaches followed in the literature regarding the front-seat passenger experience. Now we will provide a deeper analysis of the passenger-oriented studies in the literature and concept cars.

The content of the academic and industrial R&D efforts needs such deconstruction that we can position their contributions within varied dimensions of the UX. Therefore, while analysing the passenger-oriented automotive interface solutions, we will refer to Hassenzahl (2010)’s how, what and why dimensions of interacting with technology. The model investigates how a user connects his/her-self to the world through an activity with a three-level goal hierarchy. In this model, ‘what’ dimension for ‘do-goals’ refers to the tasks to be completed or a concrete goal to be achieved by users, which can defined as the functionality. At the lowest level, there is ‘how’ dimension for ‘motor-goals’ which involve all the operational steps that user has to go through while interacting with the product. At the highest level, there is ‘why’ dimension for ‘be-goals’ which is about the meaning, motivations and emotions related to that activity.

The previously mentioned research can be referred to again to exemplify how these diverse levels of interacting with technology are studied in literature. The use of emerging technologies (e.g. eye-gaze recognition, split-view displays) in front-seat passengers’ in-car interactions illustrates the investigation of the how dimension, because embodiment of these technologies has a direct influence on how we interact with the interfaces. On the other hand, the what dimension has been studied through the identification of the type of information or services that front-seat passengers are interested in. These studies have also touched upon the why dimension by explaining the positive effects of these applications on users such as ‘reduced boredom’ or ‘sense of inclusion’. It is important to mention that all these dimensions are linked: Improvements in interactions and functionalities contribute to a pleasant user experience (why dimension); and thinking about what makes a pleasant experience helps designers come up with appealing interface designs and functionalities.

The examples can be expanded with the passenger-oriented solutions that automotive companies are planning to integrate into future cars. Therefore, concept cars introduced in Geneva Motor Show (2015-2016), Frankfurt Auto Show (2015), and Consumer Electronics Show (CES) (2015-2016) were investigated with an eye to reveal the technologies and passenger-oriented solutions they have recently integrated and/or have visions to include. The official websites of the auto shows as well as other online automotive design sources including Car Magazine, CNet, Digital Trends, The Verge,
YouCar, and Autogefühl were studied. Car manufacturer web-sites were also referred when further information was needed for a specific model introduced in these shows. In total, 253 cars (53 concept cars, 200 production cars to be released in near future) were reviewed.

Each concept car has its own prominent features and they present varied innovations in styling, performance, alternative energy usage and automotive HMI (human-machine interfaces within the car). Based on the scope of the research, 13 cars offering new concepts for in-car interactions were selected for further analysis. The selection criteria were based on two questions:

1. Do the in-car interactions (automotive HMI) demonstrate anything beyond what exists in production cars?
2. Does the car provide any (front-seat) passenger-oriented infotainment solutions?

The 13 cars that successfully fulfilled one or both of these criteria include Mercedes F015, Volkswagen Golf R Touch, Kia DriveWise (CES 2015); BMW i8 Vision, Volvo Concept 26, Volkswagen BUDD-E (CES 2016); Porsche Mission E, Mercedes IAA Concept (Frankfurt Auto Show, 2015); Audi Prologue (Geneva Motor Show 2015); Ferrari GTC 4 Lusso, BMW Vision Next 100, Opel GT Concept, Skoda VisionS (Geneva Motor Show 2016).

Infotainment systems that are dedicated to the use of front-seat passengers do not yet exist in production cars; we can discuss such versions of infotainment only in the context of future car journeys. Therefore, detailed analysis of concept cars is important to identify the trends in automotive user interfaces, to investigate the use of interaction technologies and infotainment features envisioned for future travel scenarios.

The technology review of the selected concept cars was conducted as a content analysis of a varied collection of media; including the explanatory texts, visuals and videos which demonstrate the interactive features of the car interfaces. The categorization of the relevant content was mainly based on the passenger-specific automotive user interface solutions, the interaction technologies used for information provision and input, and the car infotainment features targeting the front-seat passengers / occupants (in shared systems). Further categorization of the results and the discussion can be found in the following section.

4 Results & Discussion

In this section, based on the model of Hassenzahl (2010) to explain the different dimensions of interacting with technology (why-what-how), the paper will first investigate the how dimension – ‘front seat passenger infotainment interactions’. With regards to this dimension, it will introduce new control and display configurations in the car’s interior that empower (front-seat) passengers, trends in automotive user interfaces and mostly used interaction technologies in selected concept cars. For the latter two, passenger vs. driver-oriented solutions are not differentiated, because the very same technology or interface can be reconsidered as control and display of front-seat passenger infotainment systems. Secondly, it will focus on ‘front-seat passenger infotainment features’ (the what dimension). It will provide a categorization of passenger infotainment features based on passenger interests identified in the literature and passenger-oriented infotainment trends presented in the technology review. The categories include information, communication, and entertainment. Finally, it will touch upon the why dimension – ‘enhancement of front-seat passenger journeys’. In this part, we refer to studies which identify the types of positive effect (as well as affect) that these solutions have on front-seat passengers. It will also discuss in what ways the efforts mentioned under what (the way we interact the system) and how (the infotainment features) dimension could enhance the front-seat passenger journey experience.

4.1 Front-seat passenger infotainment interactions

This section will provide the analysis of the automotive user interface solutions presented in the literature and the technology review with a focus on how (front-seat) passengers are expected to
interact with the infotainment systems. The section includes the following headings: i) New interior control and display configurations that empower (front-seat) passengers; ii) Mostly used interaction technologies; and, iii) Trends in automotive user interfaces.

4.1.1 New interior control and display configurations that empower (front-seat) passengers

Table 1 illustrates how (front-seat) passenger empowerment is achieved through different approaches in automotive user interface design. The categories range from infotainment systems dedicated to front-seat passengers (A), to more indirect solutions that integrates the front seat passenger as well to the experience of interactive infotainment systems of the cars; either through information provision extended to the front-seat passenger side (B) or by turning the whole car interior into a ‘digital social space’ (C).

Four concept cars out of 13 that were reviewed - Mercedes IAA Concept, Opel GT Concept, VW Golf R Touch, and Kia DriveWise - are not included in Table 1 as they do not provide any interface or infotainment solutions dedicated to passengers. They only have controls and displays in the central console area through which the front-seat passenger has a limited access to driver-oriented infotainment, as in the case of most of the today’s cars. However, they are included in the discussion of front-seat passenger infotainment interactions for their innovative approaches in automotive HMI design.

Volvo Concept 26 and BMW Vision Next 100 have been placed in category B. Information provision extended to front-seat passenger side only because they provide a shared information provision to front-seat passengers through extended displays. Unlike the other two cars in this category (Porsche Mission E and BMW i8 Vision) they do not offer any front-seat passenger-specific solutions that enable them to control infotainment from their cockpit.
### Table 1 Control and display configurations in interior that empower (front-seat) passengers

<table>
<thead>
<tr>
<th>A. Infotainment screens dedicated to front-seat passenger</th>
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<tr>
<td>Ferrari GTC 4 Lusso</td>
<td>Audi Prologue</td>
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<tr>
<th>B. Information provision extended to front-seat passenger side (Accessed by both front-seat occupants)</th>
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<tbody>
<tr>
<td>Porsche Mission E</td>
<td>BMW i8 Vision</td>
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</table>

<table>
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<tr>
<th>C. Whole car interior as a ‘digital social space’</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercedes F015</td>
<td>Volkswagen BUDD-E</td>
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#### 4.1.2 Mostly used interaction technologies

In this paper, the term ‘interaction technology’ corresponds to the interactive features of the automotive user interfaces such as touch recognition. The information provided for each concept car does not always contain which specific technology is used to deliver the interactivity, especially for input. For example, we can gather information about the type of modality used (e.g. touch vs. gesture recognition), how it is applied in the car interior (e.g. touch sensitive armrest vs. touch screen); but cannot always identify the exact underlying technology (e.g. capacitive vs. ultrasonic touch recognition) mostly because of the confidentiality of R&D of automotive user interfaces.

Figure 1 summarizes the type of interaction technologies used for input and information provision in the reviewed cars; how frequently the technologies are utilized, and in what ways they are applied to the car interior. Input technologies refer to the means that are utilized to control interfaces; whereas, information provision technologies correspond to any type of display or feedback that are utilized to provide information to users.
Figure 1 Distribution (x out of 13 cars) of interaction technologies (input and information provision) used in concept cars (circle’s size represents the relative frequency).

Regarding the input technologies, it is observed that touch recognition, gesture recognition, eye-gaze recognition and audio recognition are used as a replacement of the physical controls like knobs and buttons. It was a challenging task to identify the concept cars with audio recognition since it is not a visible feature. Therefore, audio recognition is added as a feature for the concept cars if it is mentioned or presented as type of input in the video or text-based sources reviewed. We can claim that at least seven out of the thirteen cars have this feature.

The categorization of the technologies for information provision was also made based on the sensory modalities used. As can be seen in Figure 1, visual display types vary from currently used LCD or LED displays to curved OLEDs, flexible OLEDs, 3D panel LED projection, head up displays and shape changing displays. In addition to visual displays, information is also communicated via haptic displays (e.g. touch sensitive surfaces or touch screens with ‘surface-haptics’ feedback) and audio displays (e.g. audio feedback). It is important to mention that a specific technology can appeal to more than one modality or can be used for both input and information provision. For example,
shape changing displays are applied as means of visual feedback in the BMW Vision Next 100 under the concept of ‘alive geometry’ (tiny triangular physical surfaces in motion to notify the driver); however, the very same technology have been studied as a haptic feedback or even as an input via changing shapes as well.

4.1.3 Trends in automotive user interfaces
This section presents the most commonly used interaction technologies in concepts cars and the trends that automotive firms followed to utilize them to enhance car interfaces, interactions and interiors. The information about the trends (see Figure 2) are as follows.

- **Touch as the most used modality.** Automotive firms started to use touch sensitive surfaces in different zones of the car interior in addition to the touch sensitive screens in the central console and dashboard.

- **Expansion in areas and ways of information provision.** There is an expansion from the conventional information provision areas (infotainment screens on central console/dashboard, instrument clusters and HUDs at driver’s side) to passenger dashboard, side doors and other surfaces of the car interior. Such expansion also applies to head-up displays, which has been rethought as a “windshield display” in concept cars. We also see novelty in the way that information is provided as in the example of “alive geometry” in BMW Vision Next 100 (2016) where tiny triangular physical surfaces in motion notify the driver about incoming dangers (BMW, 2016).

- **Increasing integration of gestural recognition.** Hand gestures are mostly utilized to control the information provided through displays expanded to the front-seat passenger side or HUD displays, where the use of touch is not an option for the driver because of the reach issue. Another motivation for the integration of gesture recognition is to decrease the number of physical controls - the visual complexity of the interior.

- **Curved displays blending into interior.** It is also observed that the aim behind the use of particular display technologies (e.g. Curved OLEDs, 3D LED Panel projection) is to eliminate the need to use flat interior surfaces just to place flat-rectangular screens on the dashboard. This brings much more flexibility to the design of the car interior and its visual aesthetics.

- **Co-located physical and digital layers.** There is an increase in interactivity of physical items in the car either through e.g. integration of LED light-based visual feedback under the mesh leather upholstery of the steering wheel (BMW i8 Vision) or HUDs which augment the outside windshield view with a digital information layer.

- **Expansion of control areas from dashboard/central console to the whole of the car interior.** As the travel scenarios change in a way that integrates more car occupants in control of interactive systems (see Table 1), it becomes necessary to create ready-at-hand control areas for them. That is why we see examples like touch sensitive arm-rests or touch-sensitive side doors. This trend is highly related to the “expansion of information provision”, especially for interfaces where control-feedback is achieved using the same interactive element, as in the case of touch-screens.
Figure 2 Distribution of (x out of 13 cars) of future trends for in-car interactions in concept car (circle’s size represents the relative frequency)
4.2 Front-seat passenger infotainment features

The previous section covered diverse ways of accessing infotainment features in a car. This section will focus on what these infotainment features are; in other words, what front-passengers will be able to do when front-seat passenger infotainment systems are realised. The infotainment features are either shared by other car occupants (See B & C sections of Table 1); or provided specifically for front-seat passengers (See the section A of Table 2).

Figure 3 Distribution of (x out of 13 cars) of infotainment features in concept cars (circle’s size represents the relative frequency)
The content analysis of the new functionalities presented in the literature and concept cars revealed three main categories of infotainment features: information, entertainment and communication. Some aspects of the infotainment features overlap with each other; therefore, it is not possible to make a distinct separation between these three categories. However, the prominent attributes of each category are as follows. Information concerns anything that passengers would like to know or learn throughout the journey; entertainment relates to anything that would help to reduce the boredom of being a passenger, which, of itself is not necessarily stimulating; communication is about sharing things with other car occupants and other people outside the car and involving them to a specific part of travelling experience through infotainment.

Most of these features can function thanks to today’s connectivity technologies and cloud systems which create a network among the vehicle and smart devices, other vehicles and the infrastructure. Following information, entertainment and communication, this paper will also touch upon other connectivity-enabled features which can be used either inside or outside of the car. These features are mentioned under a separate category because they are not necessarily about information, entertainment or communication; they are about being able to access or control all of these features while on-board or not on-board.

Figure 3 illustrates the list of all (front-seat) passenger-oriented information, entertainment and communication features together with the other connectivity features offered by the concept cars. It demonstrates that most of the infotainment features are enabled by connected car technologies. Another highlight is that the information and communication categories have been explored more in detail compared to the entertainment category. New entertainment functionalities presented in concept cars focus on how to organize media playlists rather than exploration of alternative entertainment features.

4.2.1 Information

Information provided to (front-seat) passengers in the reviewed concept cars include the i) journey and journey planning; ii) surroundings of the car; or iii) the performance of the car. See Table 2 to view additional information categories mentioned in literature.

i) The information about the journey itself and journey planning includes:

- Time, arrival time/time left to the destination
- Graphical representation of the location of the car in relation to the route
- Route distance/remaining distance
- Points of interest and stop-over locations on the route
- Navigation menus for the front-seat passenger

These features exist in the following cars and infotainment menus: Ferrari GTC 4 Lusso (Navigation), Audi Prologue (Road Trip, Personal Assist) (Figure 4), Skoda Vision (Navigation), Porsche Mission E (Navigation), BMW i8 Vision (Navigation), Volvo (Navigation), Mercedes F015 (Guided Path-Time, Guided Path-Places), and VW BUDD-E (VW Travel App).

It is important to mention that this information is given as a part of either navigation menus or other specific menus that provide the key information about the journey without complex navigation-related features. The content and functionalities of the passenger-specific navigation menus are not clear from the concept cars related sources we reviewed. However, from the literature we can add ‘tracking journey via real-time mapping’ and ‘surrounding streets information’ features (Inbar & Tractinsky, 2011) to the bullet points provided within this sub-category.
ii) Information about the surroundings includes:

- Cultural information (e.g. Information about the points of interest on the route)
- Daily practical information based on cloud data (e.g. indication of meeting place based on the agenda, indication of a specific shop based on the shopping list) (Figure 5)
- Social information: Friends/Contacts travelling around

These features are present in Audi Prologue (Road Trip, Personal Assist), BMW Vision Next 100, and Mercedes F015 (Guided Path-Places, Guided Path-People).

Regarding cultural information, the research of Osswald et al. (2013) presents which point of interests and other car surroundings related information are prioritised by front-seat passengers (see Table 2). The ‘Toll gate information’ example provided by Lee et al. (2015) shows that a diversity of the travel scenarios can enrich the examples regarding the information about the surroundings that needs to be provided to passengers. Connectivity-enabled daily practical information or social information is not mentioned in the literature.

iii) Information about the performance of the car include:

- View (and/or control) of the current driving mode (Figure 6)
- Speed
- Fuel consumption, information on the energy reserves and range
- Other performance info (e.g. boost-oil pressure-oil temperature)

Fuel information also appears as a type of information that front-seat passengers mentioned in the probing study conducted by Osswald et al. (2013). While talking about sharing in-car information with passengers Inbar and Tractinsky (2011) also give example of a Maybach car with speedometer dials attached to rear seat passenger’s side door.
4.2.2 Entertainment

Media (audio-video) players can be considered as default entertainment features in contemporary cars. What is new in concept cars regarding media playing and entertainment is enhancements brought by the connectivity. These new entertainment features include:

- **i) Intelligent media streaming:** Customised entertainment based on personal data, chosen route and network conditions (bandwidth) as present in Volvo Concept 26 (Figure 7)
- **ii) Entertainment planning:** Setting and viewing the playlist in relation to the travel route as present in Volvo Concept 26, Mercedes F015 (Guided Path-Music), VW Budd-E (VW Travel App)
- **iii) Other entertainment features** e.g. ‘Beam Cam’: Logging in to the surround cameras of other F015 cars connected with your car and seeing their view while travelling. This feature exists in Mercedes F015 (Guided Path)

Entertainment is not a concept that is deeply explored for the front-seat passenger. Having reviewed passenger-oriented studies, we can only refer to Osswald et al. (2013) where front-seat passengers mention TV, DVD movies, games, Facebook, pictures, and YouTube as possible infotainment features. Most of these features can be provided through the connected car systems, like Apple Car Play or Android Auto, to enable the access to smart device applications in car. It is mentioned under ‘Other connectivity features’ category.

4.2.3 Communication

Communication features can either contribute to **i) communication among car occupants** or **ii) communication with other people.**

**i) Communication among car occupants** can be illustrated as follows.

- Sharing data among displays dedicated to each occupant (Skoda VisionS, Audi Prologue)
• Collecting all shared information in a shared unit of information provision (Mercedes F015, VW Budd-E)
• Getting a view of rear-seat occupants, e.g. for front-seat passenger to easily keep eye on the children at the back (Skoda VisionS, see Figure 8)

The above-mentioned literature about specific in-car applications developed for passenger-driver collaboration in navigation tasks can be considered as examples of infotainment features enabling communication among car occupants (See Table 2).

![Figure 8 Watching a movie and keeping eye on the kids on the rear seats simultaneously thanks to front-seat passenger infotainment system in Skoda VisionS. Source: Car Magazine (2016)](image)

**ii) Communication with other people** is achieved in the reviewed cars via audio-video calls (Figure 9) or text messaging. This feature is provided for passengers in Skoda VisionS (chat), Porsche Mission E (Contacts), BMW i8 Vision, BMW Vision Next 100, Volvo Concept 26, Mercedes F015 (Connected Device), VW Budd-E (‘Messages’ and ‘Phone’).

In relation to communication with other people; Facebook, e-mail, contact list, SMS and Skype features and applications are listed by Osswald et al. (2013).

![Figure 9 Video chatting with a colleague in BMW i8 Vision (when autonomous driving is activated). Source: Cnet (2016)](image)

4.2.4 **Other Connectivity Features**
This section refers to connected car features, which cannot be considered only as an information, entertainment or communication feature but can be a part of the car infotainment systems, including:

• *i) Access to vehicle information and vehicle control while not on-board*: The information that can be accessed via connected smart devices (phone or watch) consists of charge/battery status, location, surround view, route information (remaining range). Vehicle control via smart devices can be illustrated with locking/unlocking the car (digital key) and calling the car to pick-up (only in autonomous concepts). Please note that these features are provided only to the owner of the cars, authorised drivers or driver-passengers of the autonomous
cars. We believe that vehicle information access and control while not on-board can be customised for other car occupants, in our case, for front-seat passengers as well.

- **ii) Smart home-car connectivity:** Access to smart home information and controls (e.g. viewing the home security camera footage, Figure 10) is presented as a feature in BMW i8 Vision and VW Budd-E.

- **iii) Access to smart devices applications:** This feature includes systems like Apple Car Play and Google Android Auto and they are only mentioned for the concept cars to be released into market in a very near future (starting from 2017). These cars are Ferrari GTC 4 Lusso, Audi Prologue - ‘Audi Smartphone’, VW Golf R Touch).

![Figure 10 Viewing home security camera footage through infotainment screen in VW Budd-E. Source: (Volkswagen, 2015)](image)

Table 2 presents the resulted categories for passenger infotainment features and how they are depicted in literature and technology review (of concept cars). The table shows that academic and industrial efforts are aligned when it comes to the identification of front-seat passengers’ needs and finding solutions to fulfil them.
<table>
<thead>
<tr>
<th>Infotainment features depicted in literature</th>
<th>Infotainment features depicted in concept cars</th>
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<tbody>
<tr>
<td><strong>COMMUNICATION</strong></td>
<td></td>
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<tr>
<td>Information about the Journey Itself, Journey Planning</td>
<td>Information about the Journey Itself, Journey Planning</td>
</tr>
<tr>
<td>• time travelled, travel duration*, estimated time of arrival**</td>
<td>• time, arrival time/time left</td>
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<tr>
<td>• distance travelled, distance to destination*, estimated distance of arrival**</td>
<td>• graphical representation of the location of the car in relation to the route</td>
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<tr>
<td>• location of the rest area, information about rest area, attractions of destination</td>
<td>• route distance/remaining distance</td>
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<tr>
<td>• tracking journey-real-time mapping***</td>
<td>• points of interest and stop-over points on the route</td>
</tr>
<tr>
<td>• traffic info, traffic lights*, traffic jam**</td>
<td>• navigation menu for the front-seat passenger</td>
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<td>• surrounding streets***</td>
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<tr>
<td>Information about the Surroundings</td>
<td>Information about the Surroundings</td>
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<tr>
<td>• shopping, hotel, restaurant, road signs, radar, sightseeing, toilet, gas station, activities, church, cinema, events, camping, picnic, swim, POI *, toll information (near toll gate) **</td>
<td>• points of interests on the route</td>
</tr>
<tr>
<td></td>
<td>• practical information based on the cloud data (e.g. indication of meeting place based on the agenda)</td>
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<td>• friends/contacts travelling around</td>
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<tr>
<td>Information about the Performance of the Car</td>
<td>Information about the Performance of the Car</td>
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<tr>
<td>• fuel*</td>
<td>• view (and/or control) of the current driving mode and speed</td>
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<tr>
<td>• speedometer (Maybach example)***</td>
<td>• fuel consumption, information on the energy reserves and range</td>
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<td>• other performance info (e.g. boost-oil pressure-oil temperature)</td>
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<td>Information about the Weather</td>
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<td>• weather* weather information of destination**</td>
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<tr>
<td><strong>ENTERTAINMENT</strong></td>
<td></td>
</tr>
<tr>
<td>• TV, DVD/movies, games, Facebook, pictures, Youtube*</td>
<td>• Intelligent Media Streaming</td>
</tr>
<tr>
<td></td>
<td>• Entertainment Planning (Setting and/or viewing the playlist in relation to the travel route)</td>
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<tr>
<td></td>
<td>• Other Entertainment Features</td>
</tr>
<tr>
<td></td>
<td>• ‘Beam Cam’: Logging in to the surround cameras of other cars and see their view while travelling</td>
</tr>
<tr>
<td><strong>COMMUNICATION</strong></td>
<td></td>
</tr>
<tr>
<td>Communication among Car Occupants</td>
<td>Communication among Car Occupants</td>
</tr>
<tr>
<td>• front-seat passenger and driver collaboration in navigation****</td>
<td>• sharing data e.g. route plan among displays dedicated to each occupant</td>
</tr>
<tr>
<td></td>
<td>• collecting all shared information (e.g. playlist) in a shared unit of information provision,</td>
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<tr>
<td></td>
<td>• getting a camera view of rear-seat occupants</td>
</tr>
<tr>
<td>Communication with Other People</td>
<td>Communication with Other People</td>
</tr>
<tr>
<td>• Facebook, e-mail, contact list, SMS, Skype*</td>
<td>• audio/video calls, text messages</td>
</tr>
</tbody>
</table>

[*] Osswald et al., 2013; [**] Lee et al., 2015; [***] Inbar & Tractinsky, 2011; [****] Trösterer et al., 2015; Perterer et al., 2015; Rümelin et al., 2013; Gridling et al.; 2012 and Forlizzi et al., 2010.
4.3 Enhancement of front-seat passenger journeys

This paper argues that there is a design opportunity for “empowering” front-seat passengers and provides examples of academic studies and automotive solutions that would enhance front-seat passengers’ journeys. The term “empowerment” is used as an umbrella term to define the main motivation behind these efforts. This section explains in what ways these new interfaces, interactions, and infotainment features can enhance front-seat passengers’ travelling experience, along with bringing empowerment to users.

The expected contributions of sharing in-car information with passengers are clearly identified by Inbar and Tractinsky (2011) as “reduced boredom”, “increased trust”, “increased sense of inclusion” for (front-seat) passengers. We can claim that studies exploring driver-passenger collaboration not only investigate pragmatic navigation solutions based on collaboration but also aim for front-seat passengers’ ‘autonomy’ and ‘competence’ (Sheldon et al., 2001; Hassenzahl, 2010) by giving them more control and responsibility in completion of driving-related tasks, ‘relatedness’ (Sheldon et al., 2001; Hassenzahl, 2010) based on increased communication between front-seat occupants, and ‘stimulation’ (Sheldon et al., 2001; Hassenzahl, 2010).

In the section “Front-seat passenger infotainment features,” we introduced these features under the categories of communication, entertainment and information. These categories also act as concepts to identify the ways of enhancing front-seat passengers’ journeys. We can link these categories to the psychological needs of the passenger Sheldon et al., 2001; Hassenzahl, 2010) as well. Accessing the information about the journey, surroundings and performance of the car can provide front passengers more ‘autonomy’ and ‘security’. It can be claimed that communication related features like audio/video calls, access to social media accounts carry potential to increase ‘relatedness’ and ‘popularity’. The feeling of ‘security’ and ‘relatedness’ can also be improved through the infotainment feature like having a camera view of rear seat-passengers in front-seat passenger cockpit. ‘Stimulation’ is also an obvious expectation from entertainment features.

Such potentials can only come true and be enhanced when the infotainment features are executed with appealing interfaces and interactions. For example, it is easy to associate media playing features with stimulation and fun; however, the user interfaces can be stimulating as well when they are used to access to information features. This argument can be generalized for any interface design, but it becomes even more to-the-point within the scope of this paper because ‘passengering’ is less a task or a pragmatic act than driving.

5 Concluding remarks

The paper identified that there has been a lack of automotive user interfaces that provide infotainment features and interactions enriching front-seat passenger’s journeys. Needs and motivations of the front-seat passengers have been neglected since the main concern in automotive HMI design has been limited to the driving activity. Based on this problem definition, the paper provides an analysis of academic and industrial efforts that investigate empowerment of front-seat passengers. The main the source for the academic studies was the automotive UX literature, whereas industrial efforts were demonstrated through the technology review of a selection of the concept cars presented in several automotive/technology shows in 2015-2016.

The paper presents examples of front-seat passenger-oriented infotainment solutions. It also contributes to automotive UX literature by categorizing the intense list of solutions based on different dimensions of interacting with technology. By reviewing these categories, readers can easily differentiate the innovations regarding infotainment system interactions (how dimension) from the new functionalities/infotainment features provided to front-seat passengers (what dimension). This will enable investigation of new relations among varied dimensions/levels of the infotainment experience; such as delivering a specific communication feature (the functionality) with a new display technology that has never been considered for the use of the front-seat passenger.
The paper also gathered the concepts that identify the expected hedonic or pragmatic qualities from passenger infotainment systems such as ‘reduced boredom’ or ‘sense of involvement’ (why dimension), which helps designers to imagine more appealing infotainment features and interactions.

The concept car examples presented in the technology review show that passenger empowerment is on the agenda of automotive companies. This empowerment has been achieved either through exclusive solutions like infotainment screens dedicated to front-seat passenger or active involvement of front-seat passengers in the use of the infotainment system. The categorizations provided in Table 1 can be considered by designers and design researchers as a selection of approaches to follow while addressing front seat passengers’ needs. However, in pursuit of any of these design approaches, there are certain conclusions that should be drawn from the analysis to better target this specific car occupant:

Most of the solutions demonstrated in the paper fall short of making use of the full potential of the available interaction technologies. Despite the new infotainment features/functionality provided, the general approach follows a ‘selective duplication of previous driver-oriented solutions’. We generally observe screens attached or extended to the passenger dashboard together with gesture or touch-based controls, although the solutions can be more flexible, such as portable displays and controls, head up displays as part of information provision, entertainment or communication. Driving is a challenging task that comes with the problem of division of attention to varied stimuli; therefore, manufacturers keep introducing new modalities (e.g. haptic feedback) in automotive HMI to rely less on the visual channel. This approach can also be introduced for the front-seat passenger. For example, there can be a switch between haptic and visual feedback in the infotainment interactions while front-seat passengers switch from resting with closed eyes to acting as a co-navigator. In fact, a technology which has been used for pragmatic purposes for the driver can deliver hedonic quality to the front-seat passenger’s user experience.

Front-seat passenger-specific infotainment has not been explored enough in production cars until now. Further investigation is needed to understand which solutions would be more favourable and worthwhile from R&D efforts to be applied into a real car. Solutions need to be tested considering different travel scenarios or contexts. For example, the relevance of the infotainment features can change based on the type of the travel. Information about the attractions of the destination is expected to be more appropriate during leisure journeys in comparison with the daily commute.

The link among the why-what-how dimensions of the front-seat passenger experience is also missing. The solutions demonstrate the most recent technologies and functionalities, but the motivations behind these front-seat passenger-oriented applications are not always clear. In other words, there is not enough exploration on how these solutions will enhance the user-experience or deliver hedonic quality as well as a pragmatic one. Designers need to reflect on their proposals with questions like “What type of positive emotions can be evoked by providing the estimated time of arrival information to passenger through a screen on the passenger dashboard, will it contribute to passenger’s sense of involvement in the travelling activity, what are the captivating ways of providing this information?” Therefore, while testing the design proposals, the research should be conducted in a way that we can investigate the links among different dimensions of the front-seat passenger infotainment experience.

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6 References