# Car User Experience Patterns: A Pattern Collection in Progress

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***Abstract*— Car user experience patterns are a systematic way to capture best practices and solutions to reoccurring problems in automotive interaction design. Combining empirical data, industry knowledge, and experts experience, they facilitate communication between scientists and industry stakeholders. In this paper, we present a newly generated set of eight car user experience patterns that describe answers to problems in automotive interaction design and engineering. These patterns are part of an ongoing project with the aim of providing a comprehensive, User Experience focused, pattern collection. The patterns presented in this paper mainly contain information on reducing potential distraction caused by the usage of in-vehicle information systems and on designing efficient in-car warning systems. They are the result of a novel approach combining scientific and industry know-how into very brief and domain-specific design problem solutions.**

***Keywords*— design patterns; pattern identification and extraction; pattern reuse.**

## I. INTRODUCTION AND RELATED WORK

The usage of patterns is well established in Human-Computer Interaction (HCI) and is advantageous for various reasons. First, patterns are a method to capture proven design solutions to reoccurring problems. Second, the use of patterns improve the design process (regarding both time and effort spent) to a considerable degree [1][2]. Moreover, scientific research in HCI also strongly relies on communicating scientific findings to the industry. By translating these findings so that they convey relevant and useful information to designers and developers, patterns can help facilitate the design process by reducing time and effort that has to be put into it.

Designing for a good User Experience (UX) has become an increasingly important topic in academia and industry [3][4][5]. User Experience can be defined as *"the users sensory, emotional and reflective response to the interaction with a system in a context"* [6]. The car industry in particular has become a fast-paced global market that can draw substantial benefits from a modular and flexible documentation of best practices.

Based on this consideration, we created a set of car User Experience patterns, of which we present the eight most recent car ones in this paper. In the following two subsections, we will give an overview on the state of the art on Contextual UX patterns in general, and our approach in particular. In Section II, we show each pattern in its entirety, and conclude with a brief summary in Section III.

### *A. Contextual User Experience Patterns*

Recently, specific domains in HCI, such as UX research, employed patterns to collect and structure their knowledge based on empirical findings [2][7][8]. This is illustrated, e.g., by Martin et al. [9] and Crabtree [10] who use patterns for organizing and presenting ethnographic material. The first who emphasized a focus on the human perspective in the history of patterns was Alexander [11]. In 2010, Blackwell and Fincher [5] suggest to adopt the idea of patterns and UX in the form of Patterns of User Experience (PUX). Such patterns should help HCI professionals to understand what kind of experiences people have with information structures.

In the same year, Obrist et al. [2] developed 30 UX patterns for audiovisual networked applications based on a huge range of collected empirical data, which was further categorized into main UX problem areas. An extension of these UX patterns, are the so-called Contextual User Experience (CUX) patterns. Accordingly, patterns are used to describe the knowledge on how to influence the users experience in a positive way by taking context parameters during the interaction with a system into account. Within their work, the authors provide a detailed description of how to structure CUX patterns in the car context. Three years later, Krischkowsky et al. [8] presented a step-by-step guidance for HCI researchers for generating patterns form HCI study insights. In particular, they intended to support User Experience (UX) researchers in converting their gathered knowledge from empirical studies into patterns. The structural foundation for the intended patterns is the so-called Contextual User Experience (CUX) patterns format, as mentioned before.

Following in the footsteps of Obrist et al. [7], we decided to pursue a triangular approach towards driver space design and cover three major UX factors via appropriate design patterns.These factors are:

- *Mental Workload Caused by Distraction* [12]: Safety is paramount in an automotive environment, and distraction is one of the major contributing factors to accidents on the road [13][14]. Especially in UX, where functionalities and interface complexities are ever increasing, this is one of, if not the, most important factors to consider regarding driver safety.
- *Perceived Safety* [15]: The increased safety gained by designing for decreased mental workload and less dis-

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traction needs to be communicated to the driver. The difference between objective and perceived safety can be relatively large. For many situations, it has to be evaluated if car interfaces should increase or decrease perceived safety.
- *Joy of Use* [16][17]: This is strongly tied to the previous factor, but is not the same. Cars have more and more become instruments that are not simply means of transportation but are also used for entertainment. Thus, it becomes important that car interfaces can be used not only without frustration, but also in a way that makes using them a joyful experience.

### B. Pattern Generation Process

The pattern generation process for car user experience patterns has been described in detail by Mirnig et al. [18]. First, an initial knowledge transfer workshop was conducted in order to provide HCI researchers with know-how regarding patterns. The HCI researchers then generated an initial set of 16 patterns following the initial pattern structure. This lead to several issues with the initial structure, so that an iteration of the initial structure took place in a second workshop. The resulting refined pattern structure consists of 9 parts: *Name* (a description of the solution of the pattern), *Intent* (a short abstract to allow quick judgment whether the pattern can be applied in a certain context), *Topics* (problem scope and addressed automotive user experience factor), *Problem* (a short but more detailed description of the problem which should be solved by the pattern), *Scenario* (an example application context of the pattern), *Solution* (the proposed solution), *Examples* (concrete examples of best practices), *Keywords* (other topics related to the pattern), and *Sources* (origin of the pattern).

In the next step, patterns were presented to industry stakeholders in a pattern evaluation workshop. Based on their feedback, the name, intent and topics section were standardized and kept brief, so it takes less time and effort to process them. The context and forces sections were combined into the new *scenario* category.

## II. PATTERN COLLECTION

We developed a list of design problems together with designers and engineers working in the automotive industry and applied the aforementioned pattern generation approach, involving the industry stakeholders at several stages in the process. The following is one part of a resulting collection of patterns, which combines scientific and industry know-how into concrete problem solutions for UX-centered driver space design problems in the automotive domain.

### A. Pattern 1: Menu Depth and Number of Options

**Intent**: This pattern is about reducing distraction caused by navigating visual menus as a secondary task.

**Topics**: Workload caused by distraction, driver, haptic, input

**Problem**: While driving, navigation of in-vehicle user interface menus causes distraction. Given the safety implications of visual distraction, it is important to minimize visual demand of these menus.

**Scenario**: Drivers interact with visual menus to access information, communication and entertainment systems. Navigating menus with high visual demand severely distracts the driver and can thus lead to road deviations and crashes. Visual demand of menus is determined by a depth/breadth-trade-off. The deeper a menu, the less menu options per page there should be. A National Highway Traffic Safety Agency (NHTSA) guideline based on current research recommends that a driver should be able to complete a task in a series of 1.5 second glances with a cumulative time spent glancing away from the roadway of not more than 12 seconds [19].

**Solution**: Designing menus with limited depth allow drivers to complete secondary tasks in a relatively short time period. With the help of an empirically derived formula provided by Burnett et al. [20], it is possible to calculate different menu structures that comply with design guidelines:

$$T = D(0.87 + 1.24 * log(B)$$

where $T$ = *time to complete the task,* $D$ = *depth of menu* where $B$ = *number of menu options. Table I* shows acceptable menu structures that comply with maximum task completion time according to the NHTSA guideline, as calculated using this formula.

TABLE I
MENU DEPTH AND NUMBER OF OPTIONS FOLLOWING NHTSA GUIDELINES

| Menu Depth | Menu Breadth |
|---|---|
| 3 | 12 |
| 4 | 5 |
| 5 | 3 |
| 6 | 2 |

**Examples**: see Figures 1 and 2.

### B. Pattern 2: Display Touch Field Size

**Intent**: This pattern is about determining the optimal touch screen target size.

**Topics**: Workload caused by distraction, driver, touch screen, visual, haptic, input

**Problem**: Navigating in-vehicle displays while driving causes distraction, leading to road deviations and possibly to crashes. Thus, visual demand of touch screen menus has to be minimized while preserving maximum usability.

**Scenario**: Because they are easy to use and to understand, touch-screen interfaces are more and more used for operating in-vehicle systems. Drivers use them to control entertainment and navigation features provided by these systems as a secondary task. The key factor for navigating these displays easily is the size of the touch target like a menu button [21]. Subjective usability ratings, as well as objective measures like task completion time and error rate heavily depend on this factor.

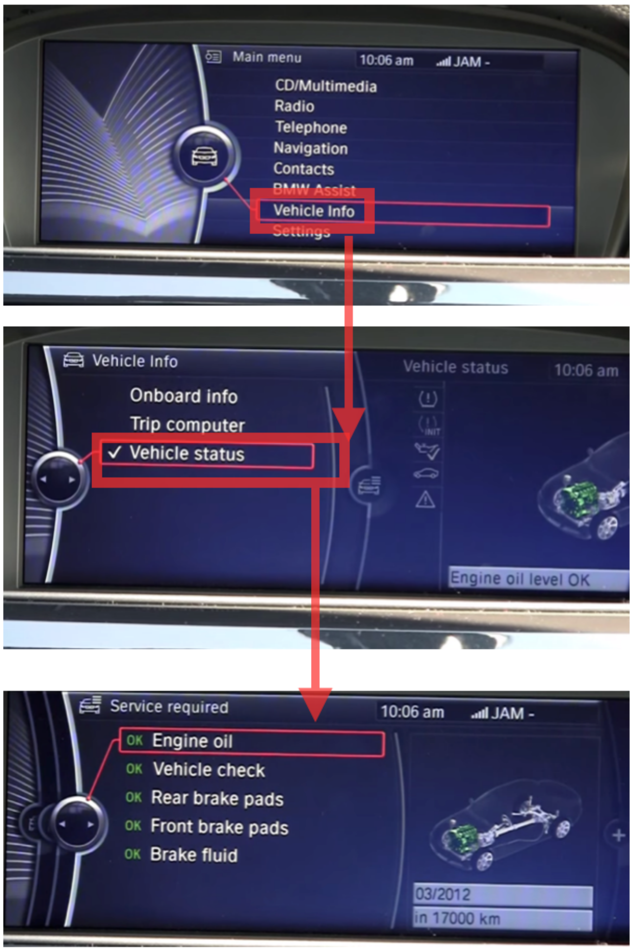


Figure 1. BMW iDrive - accessing vital information requires only three navigation steps.

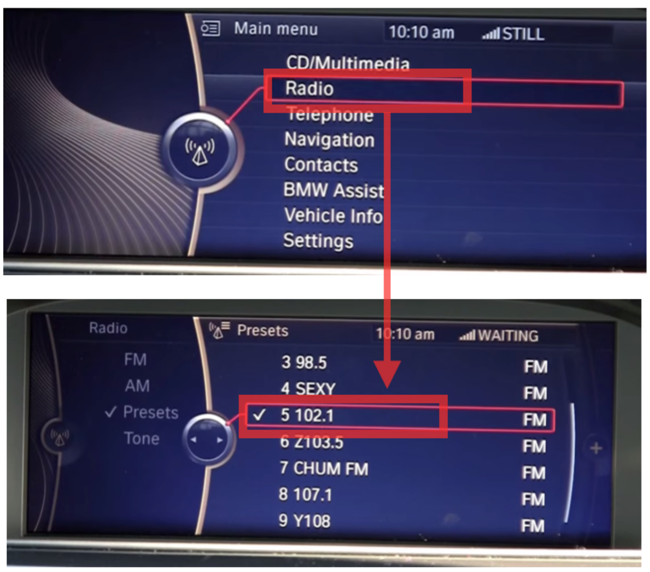


Figure 2. BMW iDrive - changing the radio station requires only two steps.

**Solution**: Touch targets need to be large enough in order to minimize task completion time and error rate. Design guidelines suggest a minimum contact surface area of 80 mm [19]. However, in a recent driving simulation study that focused on touch target size for in-vehicle information systems, the authors determined that a touch key size of at least 17.5x17.5 mm minimizes navigation error rate, lane deviations, driving speed variation and glance time while maximizing subjective usability ratings [22]. While touch screen size and overall visual complexity of the menu always have to be taken in consideration, the recommended touch key size may serve as a starting point for menu design.

**Examples**: See Figure 3.


Figure 3. Apple Car Play menu.

### *C. Pattern 3: Auditory Informations and Warnings*

**Intent**: this pattern is about designing auditory informations and warnings that are quick to capture and easy to comprehend.

**Topics**: perceived safety, driver, acoustic, output

**Problem**: When using only visual warnings, driver distraction can occur. Still, drowsiness and inattentiveness increase the risk of traffic accidents. Thus, it is still necessary to direct the drivers attention to potential dangers by different means.

**Scenario**: Well-designed auditory warning systems can serve this purpose. Perceptibilty of auditory warnings depends on loudness, background noise and complexity. Also, the driver needs to know which actions have to be taken to react appropriately.

**Solution**: Different warning techniques are appropriate for different situations. According to Bliss and Acton [23], verbal speech notifications and auditory icons (sounds with real-world representations, e.g., the sound of a car engine) are equally efficient when it comes to response accuracy and reaction time. Auditory warnings also have to convey enough information to be accurately understood. Due to driving comfort reasons, warnings of low urgency should not be annoying and can even be quite pleasant, while high-urgency warnings are bound to be annoying [24].

**Examples**: **Table II** shows auditory warnings for some common situations of varying urgency. Empirical work on the perceived urgency of speech based warnings has been done [25].

### *D. Pattern 4: Choosing the Best Modality for Warning Displays*

**Intent**: this pattern is about choosing the right warning display modality for different situations, combining different

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TABLE II
RECOMMENDED WARNINGS FOR COMMON SITUATIONS OF VARYING URGENCY

| Urgency | Speech Based Warnings | Auditory Icons | Appropriate Situation |
|---|---|---|---|
| Informational (low) | Signal words that convey low urgency: ”Notice”, ”Information” | Pouring water, steam, released air | Low petrol and oil levels, low tire pressure |
| Warning (moderate) | Signal words that convey medium urgency: Warning, Caution | Shutting car door, Roaringmotor sound, squeaking sound | Car door opened, speed limit exceeded, hand brake on |
| Critical (high) | Signal words that convey high urgency: Danger | Car horn, car crash, alarm siren | Blind spot overtaking, car drifting off road, collision possible |

modalities if adequate.

**Topics**: perceived safety, driver, multimodal, output

**Scenario**: In-vehicle information system (IVIS) information needs to be delivered effectively while minimizing the interference with driving. Display modality has a significant impact on the performance of in-vehicle information systems. Visual, auditory and tactile displays all have their advantages and disadvantages [26]: Visual warnings can be inspected at the drivers own pace and can be viewed multiple times. However, they cause visual distraction from the driving task and can be overlooked. Auditory warnings can be picked up without causing visual distraction, but they require the drivers full attention when they are displayed. Tactile warnings are highly noticeable, not influenced by noise and have no visual demand, but they are limited to a few types of information, such as simple alerts. In order to maximize IVIS efficiency, designers have to choose carefully between the different modalities.

**Solution**: When choosing between auditory and visual presentation, table III offers decision guidelines based on current empirical research for a variety of cases. Some of these cases will probably benefit if combined with another display modality.

**Examples**: Figure 4 shows combined auditory and visual warnings. See [27] for a live demonstration.

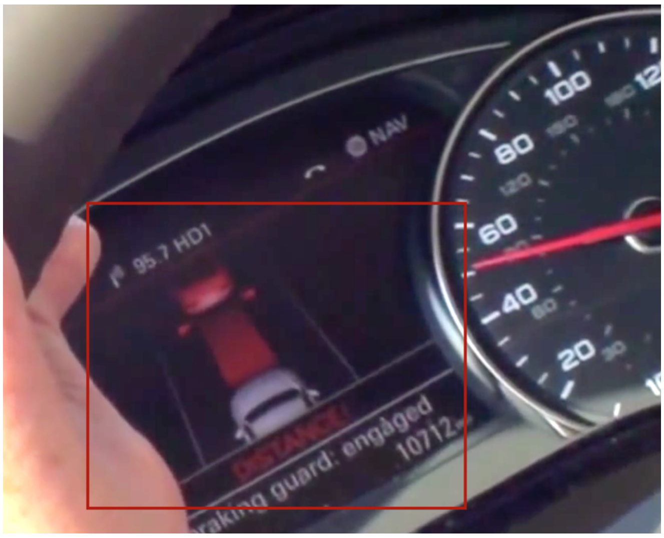


Figure 4. Audi A8 Distance Warning through a combination of auditory and visual warning displays.

*E. Pattern 5: IVIS System Response Time*

**Intent**: This Pattern addresses the role of system response time while operating in-vehicle information systems by touch interfaces or hardware keys and its influence on driver distraction and comfort.

**Topics**: Workload caused by distraction, joy of use, driver, keys, visual, haptic, input

**Problem**: While getting more and more complex, many modern in-vehicle information systems possess significant delays when using them because of the sheer amount of information that they have to process. The influence of system response time - the delay of a systems response after user input until it is ready to take new commands - has been discussed as a potential source of driver distraction and annoyance [28].

**Scenario**: Drivers use in-vehicle information systems for a wide variety of functions. While navigating their menus, the IVIS processes large amounts of information, which may lead to long and uncertain loading times.

**Solution**: Keep system response time below 250 ms. According to current design guidelines [19], control feedback should be given within 250ms after the input. A study by Utesch and Vollrath [29] showed that longer feedback delays (500 or 1000 ms) dont impair driving performance but caused significant annoyance in drivers. Keep system response times constant. It has also been shown in this study that delays that vary in their length distract the driver, while constant delays cause less off-road glances. It can be concluded that feedback delays should be kept constant so that waiting times for system response are predictable. For longer delays, use additional feedback modalities. According to guidelines of the European Commission [30], if system responses take longer than 250 ms, the system should inform the driver that it has recognized the input. If longer delays (500 ms and above) are inevitable, Utesch and Vollrath [29] recommend using acoustic or tactile feedback to indicate system readiness, as this will reduce off-road glances.

**Examples**:

1. Demonstration of a 2015 Audi MMI System, showing constant and short system response times [31].

2. Demonstration of a BMW 5 Series iDrive, showing long but constant delays [32].

3. Demonstration of an Apple CarPlay IVIS in the Ferrari FF showing long and variable delays. This might cause distraction and annoyance [33].

TABLE III
RECOMMENDED WARNINGS FOR COMMON SITUATIONS OF VARYING URGENCY

| Case | Primary Modality | Reason | Combine with... |
|---|---|---|---|
| High priority messages | Auditory[34][35] | Visual warnings alone are likely to be overlooked | Tactile [36] for decreased reaction times |
| Complex secondary task | Auditory[37][38][39] | Further distraction due to increased glance duration | Visual[40] for reduced reaction times and less navigation errors |
| Driving task is highly demanding, e.g., high driving speed | Auditory[37][38][39] | Divided visual attention poses a security risk | |
| Displaying instructions, commands, warnings or alarms | Auditory [41] | Speech is more suitable for this information type | Tactile [42] |
| Auditory message cannot be kept short and precise | Visual [43] | Auditory messages that are too long cause severe distraction | |
| Driver performs auditory tasks | Visual [25] | Auditory perception is partially or completely blocked | Tactile [44] for reduced lane deviations and annoyance, increased pleasantness |

### *F. Pattern 6: In-Vehicle Display Icon Size*

**Intent**: this pattern addresses recommended IVIS icon sizes.

**Topics**: Joy of use, driver, icons, visual

**Problem**: IVIS displays transport various informations, some of which require quick and accurate recognition. However, as in-vehicle displays have to convey more and more information, available space on in-vehicle displays becomes sparse.

**Scenario**: Icons are a way of presenting information in a spatially condensed, yet clearly understandable way. When relying on icons, the driver needs to be able to quickly grasp and process information, which in turn requires that icons can be easily recognized.

**Solution**: According to Zwaga [45], icons perform better than text displays only if they are well designed. According to FHWA guidelines [46], choosing the adequate size for an icon can be determined with the following set of formulæ. See Figure 5 for an illustration of visual angle, distance and symbol height (where Symbol Height = the height of the symbol; Distance = distance from viewers eyepoint to the display; Visual Angle = angle in degrees. Height and Distance use the same unit of measure).

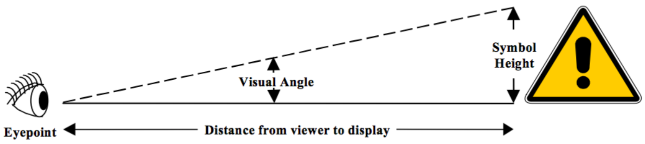


Figure 5. Relationship Between Viewing Distance, Symbol Height and Visual Angle.

**1. If viewer distance and Symbol Height are known, the following formulæwill calculate the distance.**

$$arctan(\frac{Symbolheight}{Distance}) \quad (1)$$

or

$$\frac{3438\frac{Height}{Distance}}{60} \quad (2)$$

**2. If distance and visual angle are known.**

$$Distance[tan(VisualAngle)] \quad (3)$$

**3. If visual angle and symbol height are known, the following formulæwill calculate the distance.**

$$\frac{Symbolheight}{tan(VisualAngle)} \quad (4)$$

**Examples**: See Figure 6.

Figure 6. Audi A4 2008 Dashboard Icons, taken from the users manual. [47]

### *G. Pattern 7: Visual Display Colour Choices*

**Intent**: this pattern is about choosing adequate colours for visual displays.

**Topics**: Joy of use, driver, colors, visual

**Problem**: IVIS displays transport various informations, some of which require quick and accurate recognition. However, as in-vehicle displays have to convey more and more information, they still need to be processed quickly.

**Scenario**: IVIS displays have to display information in a clear and efficient way. One way to achieve this is picking adequate colors for displays, so that reading and recognizing symbols can be accomplished without delay.

**Solution**: According to NHTSA guidelines, visual display colors should comply to a number of standards.

- Avoid using red/green and blue/yellow combinations so that color blind drivers can process the display easily.
- According to a survey conducted by Lee and Park [48], senior people prefer combinations with distinc-

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tive brightness contrasts between foreground and background color because of their better legibility.

- Displays that are too colorful distract the driver in various ways. Excluding black and white, a maximum of five different colours should be used.
- Use different colours for different priorities, e.g., red for critical alerts, amber for warnings, white for information.

Visual displays are easier to process if high color contrasts are used. A driving simulation study showed that inefficiently designed car displays strongly increase reaction times in driving tasks. They also increase reading errors [49]. Table IV shows color contrasts that guarantee high legibility.

TABLE IV
RECOMMENDED COLOR CONTRASTS FOR IVIS DISPLAYS

| | |
|---|---|
| Black/yellow | Black/yellow |
| Black/white | Black/white |
| Black/orange | Black/orange |
| Blue/white | Blue/white |
| Green/white | Green/white |
| Red/white | Black/yellow |

**Examples**: See Figure 7. This dashboard relies on white-on-black and orange-on-black contrasts which are highly visible. Orange is the only color besides black and white.


Figure 7. Dashboard with color contrasts that are highly visible.

### H. Pattern 8: Physical Buttons Versus Touch Screen Interfaces

**Intent**: this pattern addresses the question whether touch screens or physical buttons should be used.

**Topics**: workload caused by distraction, driver, touch screen, visual, haptic, input

**Problem**: Current touch-screen devices provide no tactile feedback concerning control orientation, location, separation from one another. While driving, they can not be operated with eyes on the road, which in turn leads to long off-road glances. NHSTA guidelines [19] suggest that touch interfaces should not be operated while driving. On the other hand, touch screen devices provide much more flexibility,


Figure 8. BMW iDrive screen, showing blue-on-white contrasts with an orange highlight.

which is needed to operate modern, feature-rich in-vehicle information systems.

**Scenario**: Drivers use in-vehicle information systems for a wide variety of functions. Ways to navigate through the increasing number of functions are getting more and more complex. Touch screen interfaces are getting more and more popular, but navigating them while driving is highly distracting.

**Solution**:

1) While driving, limit the amount of time spent to interact with touch devices. NHTSA recommends a maximum of six touches for every 12 seconds period [50]. Physical buttons do not require such strict regulations as their functionality is limited and they are not as visually distracting. Thus, functions that must be available to the driver while the car is moving should be represented by physical buttons or clearly identifiable, big touch buttons. Recommended limitations are as follows
   - For touch devices **without** haptic feedback, limit touch screen interactions to six touches for every 12 seconds.
   - For touch devices **with** haptic feedback, limit touch screen interactions only to certain functions.
   - No restrictions apply to physical buttons while driving.
   - No restrictions apply while standing.
2) Equip touch devices with haptic feedback. According to Harrison and Hudson [51], touch screens lead to a high number of off-road searching glances and require long periods of operation time. They also found that this could be mitigated by provide touch screens with haptic feedback, which is confirmed by other studies [52]. Studies suggest that this kind of feedback greatly increases performance and reduces operation time. If haptic feedback is used, touch devices still should to be limited to the functionality provided by traditional physical buttons.
3) Also, consider alternative input methods that dont require visual attention (e.g., voice interaction).

**Examples**: See Figure 9.

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Figure 9. VW Passat dashboard which combines few physical buttons with a well-readable touch display.

## III. CONCLUSION

In this paper, we presented a collection of patterns, which deals with recurring questions of automotive design as reported by designers working in that area. By relying on design guidelines as well as empirical research, the collection tries to bridge the gap between government regulations, scientific findings and industry needs. These patterns were intended to be of direct practical use for automotive designers. The pattern structure and length, which we described in earlier work [18], has been fit to stakeholder demands, resulting in patterns with an increased emphasis on brevity and conciseness. The car User Experience patterns proposed in this paper constitute a small part of a constantly growing collection of design knowledge. The speed of innovations, the complexity, and the range of functions of car interfaces is increasing constantly. In addition, even if there are more and more connections between single car interfaces, innovations do not necessarily occur in parallel. Thus, an equally dynamic approach to document best practices in design is required. This pattern collection shows how a pattern approach to car UX design can meet these demands. The pattern collection will continue to grow into a substantial body of car UX design knowledge, which covers at least three of the most important UX factors for driver space design [53].

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