

An expert informed approach to assess challenges in automotive HMI-development and their implications on development processes

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Abstract. The automotive industry faces a broad variety of different challenges, especially with regard to HMI development. One significant lever for improvement is optimizing the applied processes during development. In order to identify the exact challenges relevant for HMI development and to find requirements for an ideal HMI development approach, 15 semi-structured expert interviews are conducted. By that, a total of 274 challenges and 101 requirements are identified, consolidated into a set of 17 clusters with 54 sub-clusters. Thereby, a foundation for future process optimization is set.

Keywords: HMI development · Development process · Automotive · Expert interview · Interaction concept development

1 Introduction and Background

The automotive industry faces a broad variety of different challenges. With regard to HMI, the number and diversity of functions in comfort, infotainment and assistance systems have been steadily increasing in recent years [1]. Further, the customer expectations are rapidly changing based on their experience with consumer electronics [2]. As a result, the interaction concept itself and its development have become progressively complex [3]. Although there are different development approaches available that claim their capability to overcome these kinds of challenges, they usually stem from the IT sector. The automotive industry on the other hand needs to follow different rules, as a modern vehicle is much more complex and safety critical compared to regular CE devices, which is especially valid for the driver-vehicle interaction [3]. Despite the differences, agile development approaches have not been checked for suitability nor adapted for automotive HMI design so far, although agile development approaches are already applied in the automotive domain.

With that in mind, it is the ambition of this paper to gather an overview of challenges and requirements in automotive specifically relevant for the development of interaction concepts. Furthermore, potential implications of the identified challenges on the process of development are discussed.

2 Methodology

As the challenges and requirements are manifold and may deviate between different companies, an explorative method seems appropriate for assessment. Furthermore, the consolidated interviewees should be sufficiently experienced, as they need to recognize and articulate challenges and requirements which are probably not well-known. Therefore, a series of semi-structured expert interviews is chosen. The interview guideline is created following a four-step structure. First, all questions of interest related to the research subject are collected, strongly based upon previous research (see [4] for more details). The questions are then reviewed for suitability, considering the necessary prior knowledge, phrasing and factual questions. Next, the resulting questions are grouped according to their content. In a final step, the different groups are each assigned a narrative term, being as simple as possible to serve as an impetus to each section. [5] The resulting interview guide is then tested with four experts and refined according to their feedback and the experience gained. In total, the interview guide comprises 13 leading questions in the *Open questions section* with additional nine *closed questions*. The former contains the groups *Challenges today*, *Future challenges*, and *Requirements* whereas the latter is focussed on development approach *Characteristics* (Fig. 1). Within these groups, questions focus either generally, on development approaches, or on the interviewee's employer. This shift in the questions focus shall facilitate a change of perspective for the interviewee and hence help to compile a more holistic understanding of the described challenges respectively requirements. Targeted time investment for the interviews is approximately one hour.

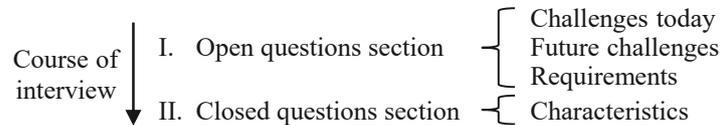


Fig. 1: Structure of the interview guideline

The approach for data processing is shown in Fig. 2. First, all interviews are transcribed by two researchers individually, noting all consistent statements by expert i (*Statement Set_{iA}* and *Set_{iB}*). Afterwards, these two transcriptions are compared and merged. Simultaneously, a preliminary cluster is assigned to each statement and tagged (“Challenge” or “Requirement”). In case of discrepancies between the two statement sets, the original recordings are checked. If the same core aspect is mentioned multiple times by one expert, only a single, merged statement is considered further. The merged sets of statements for each interview (*Statement Set_{i∈n}*) are then combined to a unified set of all statements. With that *Total Set*, a number of quality checks are performed, looking for any anomalies in the data distribution (including distribution of statements among experts and clusters, as well as among challenges and requirements). Finally, the assigned clusters are refined, and more detailed sub-clusters are assigned. New sub-clusters are created as soon as two or more experts are stating a similar aspect. Remaining statements within one cluster are grouped in a commingled sub-cluster “Divers”.

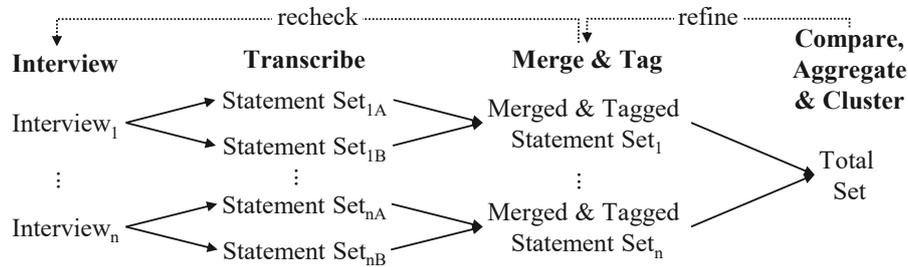


Fig. 2. Transforming procedure of interview results

So far, interviews have been conducted with 15 different experts from OEMs, Tier 1 suppliers as well as R&D companies, comprising consultancies, development companies as well as academic institutes. Each expert has a strong background in HMI design respectively development. As of yet, seven employees of OEMs, five employees of Tier 1 suppliers and four employees of R&D companies have been interviewed. 14 experts are located in Germany and one expert is resident in Italy.

3 Results

3.1 Open question section

The Total Set of statements consists of 375 individual statements that are considered in the following analysis. These statements are assigned to 17 main cluster, with additional 54 sub-cluster. Thereof, 12 cluster comprise mixed statements (“Divers”), which are not considered any further in the analysis.

To identify the most relevant sub-cluster, a share S of individual experts contributing to a specific sub-cluster is calculated. Table 1 shows the resulting clusters with their sub-cluster and the corresponding share S .

Table 1: Cluster and sub-cluster (in alphabetical order); S = individual experts contributing to a specific sub-cluster / total number of interviewees

Cluster	Sub-cluster	S	Cluster	Sub-cluster	S
Business model	New opportunities	20%	Product complexity	Flexible architecture	20%
	Updateability	20%		General	73%
Competition	Costs	40%		Simplicity vs. functions	13%
	Dependencies	13%		Tier1	13%
	Pressure	33%	Automated driving	40%	
Decisions	Management opinions	67%	Product requirements	Legislation	40%
	Speed	40%		Lifetime	13%
	Strategy	27%		Verification	20%
Development approach	Communication	20%	Prototyping	Efficiency	13%
	Freedom	20%	Requirements engineering	Unclear user needs	27%
	General	60%		User centricity	47%
	Interdisciplinarity	67%		Validating objectives	13%
Dev. speed	User centricity	40%	Volatility	40%	
	Time pressure	53%	Safety	Interaction safety	47%
Evaluation	Discard ideas	13%	Uncertainties	Automated driving	33%
	Early, often, dynamic	67%		User behaviour	40%
	Objectivity	20%	User expectations	CE expectations	60%
Knowledge	General	27%		High demand	20%
Mindset	Risk aversion	47%		Heterogenous	60%
	Compatibility	60%		Intuitiveness	53%
	Organization	Division coordination	53%		
Legacy		40%			

In the following, sub-clusters with a share S above 50 % are discussed in more detail (in alphabetical order).

Oftentimes decisions are not only based on objective data but instead subjective preference of the decision-maker. One reason to this is the difficulty to find objective measures for the variance of HMI related topics. In addition, decision-makers are eventually not an expert in the field and may not have a thorough understanding of study results or may lack capabilities to abstract. These issues are covered in the sub-cluster *Decisions – Management opinions* which achieves the second highest share S among experts (67 % of the experts provide at least one statement assorted to that cluster; this share is achieved by three clusters). Yet, most experts do formulate a challenge rather than a direct requirement on how to face that challenge (14 challenges compared to only 2 requirements). As a countermeasure against subjective decisions and to increase stability of decisions, it is probably beneficial to find suitable KPI and to recap past decisions prior to new decisions.

Within the *Development approach – General* (S = 60 %; 7 Challenges; 7 Requirements) the experts denote traditional development approaches as rigid and slow. This could lead to misdevelopments, as product requirements may change during development. Despite these disadvantages, one expert mentions clear handover scenarios as one positive aspect of waterfall style development approaches, which are referred to as one example for a traditional development approach. To overcome the challenges with

rigid and slow traditional waterfall style processes, a development approach for HMI should consider agile aspects. Especially fast-paced iterations between development and evaluation are considered as important aspect, in order to be more innovative.

The sub-cluster *Development approach – Interdisciplinarity* achieves the second highest share also (S = 67 %; 3 Challenges; 10 Requirements). Despite its overall relevance, only two experts do see challenges within that sub-cluster. The majority agrees on the relevance and importance of interdisciplinary collaboration, also across different domains or business units. Hence, an ideal development approach would facilitate cross-functional collaboration and inclusion of all relevant disciplines as early in the development process as possible. In addition, it might be beneficial to include persons from precedent or subsequent development steps, e.g. including persons from series development already in the concept development.

There is a rigorous time pressure on automotive development in general, but it is especially severe for HMI development in particular. One reason for that are customers comparing the vehicle HMI with CE devices, whereas the latter usually show a much higher renewal rate and innovativeness. This leads to the issue, that a vehicle's HMI might look old-fashioned at start of production already. Given these challenges, the experts state that the development approach must facilitate a timely provision of results. An increased development speed may eventually be achieved by focussing more on the software parts. These aspects are covered within the sub-cluster *Development speed – Time pressure* (S = 53 %; 10 Challenges; 2 Requirements).

Evaluation - Early, often & dynamic (S = 67%; 4 Challenges; 9 Requirements)

Evaluating concepts very early is not always easy (e.g. if users cannot be involved due to confidentiality). Nevertheless, a dynamic perception of an HMI by end users is required as sole hardware testing (like HIL) is not sufficient to identify issues with the interaction concept or ergonomics. Experts mention that an HMI development approach should consider early and frequent evaluations, including the users. Thereby, dynamic perception of the HMI is required, as static demonstrations are not sufficient for solid decision-making.

Organisation – compatibility (S = 60%; 4 Challenges; 8 Requirements)

Whenever different development approaches coexist, exchanging results is difficult. Therefore, one development approach may fail within a specific department if it is incompatible with the rest of the organisation. For developing a vehicle, different development approaches may coexist. Consequently, an HMI development approach must be compatible with the overall organisation as well as with other involved development processes. Eventually, this can be realized by suitable fixed milestones.

Collaboration is important, yet difficult to organize. Especially connecting the right people at the right time and thereby ensuring correct knowledge transfer. Given this challenge, an HMI development approach should facilitate the exchange between different departments, probably by providing synchronisation points. These aspects, covered in the sub-cluster *Organisation - Division coordination* (S = 53%; 6 Challenges; 5 Requirements), are strongly related to the aspects mentioned in sub-cluster *Development approach – Interdisciplinarity*.

When looking at the results, the sub-cluster *Product complexity – General* achieves the highest share amongst the interviewees (S = 73%; 17 Challenges; 0 Requirements). Many experts do see an increase in product complexity. Only one person expects a decrease due to a reduced number of ECUs. Besides the number of different functions

that need to be integrated, demanding and diverse product requirements make development complex. At the moment, there are no methods available that support the developers in identifying potential target conflicts within all the interdependencies. Although there is a high agreement among experts that complexity is an important challenge, no direct requirements are stated to handle this topic.

Users have high expectations of their vehicle. It should work as smoothly as their CE devices, offer a lot of different functionalities (including the ones known from CE devices), and it should be connected to the rest of the world. Yet, it needs to be easy and safe to operate. Although there is a high consensus among experts that a users' CE experience does have an important influence on in-vehicle HMI, no direct requirements on automotive HMI development approaches are stated (sub-cluster *User expectations - CE expectations* S = 60%; 21 Challenges; 0 Requirements).

User requirements – Heterogenous (S = 60%; 12 Challenges; 0 Requirements)

Vehicles are offered worldwide to a large, heterogeneous group of potential customers. This is challenging for HMI design as user have different abilities (ergonomic and cognitive), come from different cultural backgrounds and speak different languages. Similar to the sub-cluster *User expectations - CE expectations*, there is a substantial consensus among experts about the challenge itself, yet no direct requirements are stated on how it could be resolved.

User requirements – Intuitiveness (S = 53%; 9 Challenges; 0 Requirements)

An intuitive operation is key for user satisfaction. That means, no learning should be required. To achieve this, the user must be able to establish a correct mental model, even for more complex functionalities (including multimodal operation). For HMI development approaches a sufficient focus on usability is required.

3.2 Closed questions

At the end of each interview, several closed questions were asked with regard to the characteristics of an ideal HMI development approach (Fig. 3).

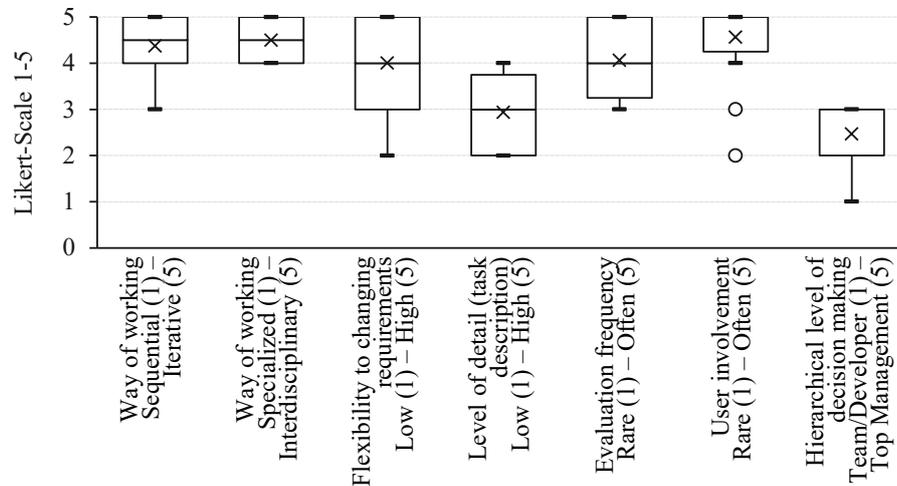


Fig. 3: Experts answers to the closed questions (n=15)

Regarding the *Way of working*, experts answer fairly consistent: the work should be in an iterative and interdisciplinary fashion. Multiple reasons for that are already stated in the open question section above.

The development approaches' flexibility to adapt to changing requirements (*Flexibility to changing requirements*) on the other hand is rated less consistent. On the one hand, being able to react flexible to changes allows to consider e.g. fluctuations in customer expectations or other changing boundary conditions. This ability could increase customer satisfaction and be considered as "state of the art" or "innovative". On the other hand, a negative impact on efficiency may arise from too volatile requirements. Conclusively, the development process should allow for necessary changes in requirements. Yet, these changes should be well chosen and documented. As mentioned by some experts in the open question section, available requirement management tools do provide sufficient support for tracking changes.

The development process should be described and documented in *Level of detail* (regarding the task description of the development approach) that sufficient standardization and support for the developer is achieved. Yet, it should not be too precise and detailed in order to avoid inflexibilities or too rigid boundaries that do not fit the varying requirements of individual teams.

Development results should be evaluated frequently (see *Evaluation frequency*), one expert suggests weekly tests with customers in the open question section. In addition, it was proposed to integrate SW-inspired testing routines (e.g. automatic unit testing), also regarding legislation. Such testing routines need to be developed and established for the field of HMI. In the long term, these tests could help to reduce testing time and costs, which was stated as an important challenge for the future multiple times.

Following a user centric development approach is considered as a very important aspect in the open question section. That is reflected in the closed question *User involvement* as well, as most experts agree to include users frequently in the development. Yet, there are two outliers ($<1.5IQR$), rating the frequency of involvement at 2 respectively 3. The two corresponding experts do not show any fundamental deviation regarding the other

questions, so that there is no indication to ignore these answers. Unfortunately, no explanations for these results were given by the experts themselves.

On average, the experts propose more decision-making competency on team/developer level (see *Hierarchical level of decision-making*). As mentioned multiple times during the open question section, it may slow down development time if too many decisions are made on higher level management. In addition, higher management may not be able to oversee all conceptual consequences from singular decision. In contrast, higher management does have a better overview on the company's overall strategy. By that, decisions may be better for the overall system/company although the individual part may be assessed differently by the experts. Nevertheless, there seems to be a need for some decisions to be made by upper management, while more detailed decisions should be made by the developing team.

4 Discussion

The answers given by the experts are quite homogenous from two perspectives. Firstly, the answers of each expert are consistent in a way that the ones given in the open question section fit well with the ones given in the closed questions. Secondly, answers across experts lead to a homogenous picture as well. However, most experts do have a similar cultural background, as 14 out of 15 are resident in Germany. Although their employers are global companies, the cultural background may affect the answers given. Therefore, it would be beneficial to extend the interviews and include more experts from other countries across the globe.

So far, only the results are described as they are given after data processing. In total, more challenges are mentioned, compared to the number of statements with direct requirements (274 challenges compared to 101 requirements). This effect is at least partially a result from the interview's structure as the majority of questions aim at challenges. Yet, finding suitable countermeasures to appropriately face the identified challenges is important. Therefore, the identified challenges need to be translated into requirements for development approaches. This is particularly important for the sub-cluster, where no requirements were stated (e.g. *product complexity – general* or *User expectations – CE expectations*). In addition, not all stated requirements imply a potential approach on how to achieve the formulated targets. That means, even though there is a list of favourable characteristics of an HMI development approach, these need to be interpreted and associated with a potential solution approach. In future work, available development approaches can be contrasted with these requirements. Thereby, shortcomings can be identified, and potential improvements devised.

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