Research knows best, but how to communicate distraction measures practically in an industrial context

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Abstract: Selection and comparison of human-factors related measures for evaluations of in-vehicle devices involves weighting of multiple criteria. It may result in a complex decision-making process for the practitioner, specifically in a time pressured industrial context. Visual information seeking has successfully been applied to reduce the complexity of datasets in healthcare and other fields. Information is presented visually and divided in 'Overview', representing the data by its characteristic criteria, and 'Details', which are presented on demand. This division reduces information load for the user and eases comparison based on characteristics. This project, first, aims to understand what criteria practitioners use to decide about the suitability of a measure for an in-vehicle evaluation. Secondly, criteria practitioners use to select measures are implemented in a new interface approach based on methods of visual information seeking to support users in the selection and comparison of human-factors related measures for in-vehicle evaluations. Overall, the interface exposes practitioners to new measures, enables them to rapidly compare measures, and obtain information to practically apply them.

1. Introduction

Distracted driving is a major contributor to accidents; it is involved in one of ten cases of road fatalities [1]. Guidelines, such as the National Highway Traffic Safety Administration (NHTSA) [2], have been introduced to help to reduce the effects of driver distraction. However, guidelines only give limited information as to what criteria distraction should be measured against. Many possible measures for driver distraction exist. How do we make sure we pick the right measure, especially in time-pressured industry or with novice users? Visual information seeking (VIS) could present users at a glance with measures from a guideline, and other measures. Those measures could then be compared visually by criteria collected from several sources in literature. This paper explains the process of designing and evaluating a VIS interface for HF measures.

There exist various measures to assess the demand of interaction with an in-vehicle device. Understanding and deciding upon the most suitable of those measures involves weighing of multiple criteria. So far, solutions have collated measures in tables or spreadsheets. This allows the user to gather and organise measures. However, tables and spreadsheets do not facilitate exploration of new or previously unknown measures. It takes time to get an overview of a measure's advantages and disadvantages in a tabular presentation comprising in-depth information of it. People then require an elaborate strategy of how to filter a set of measures in the table in order to obtain certain information.

VIS can communicate large amounts of information effectively in an exploratory way, in this specific case human factors measures from research literature, and can simplify retrieval and comparison of measures through reducing information shown at once (Fig. 1). First, the interface shows an overview of the dataset's characteristics, details are presented when requested [3]. Overview information shows characteristics of the data, such as title, year and genre for a film (Fig. 1). With an open filter menu next to the overview, users can rapidly reduce the shown information to a set that is most interesting. Users can then obtain detailed information in the reduced set, e.g. by a click on a film of interest. VIS has been successfully applied in domains such as health care [4], or consumer products [5].

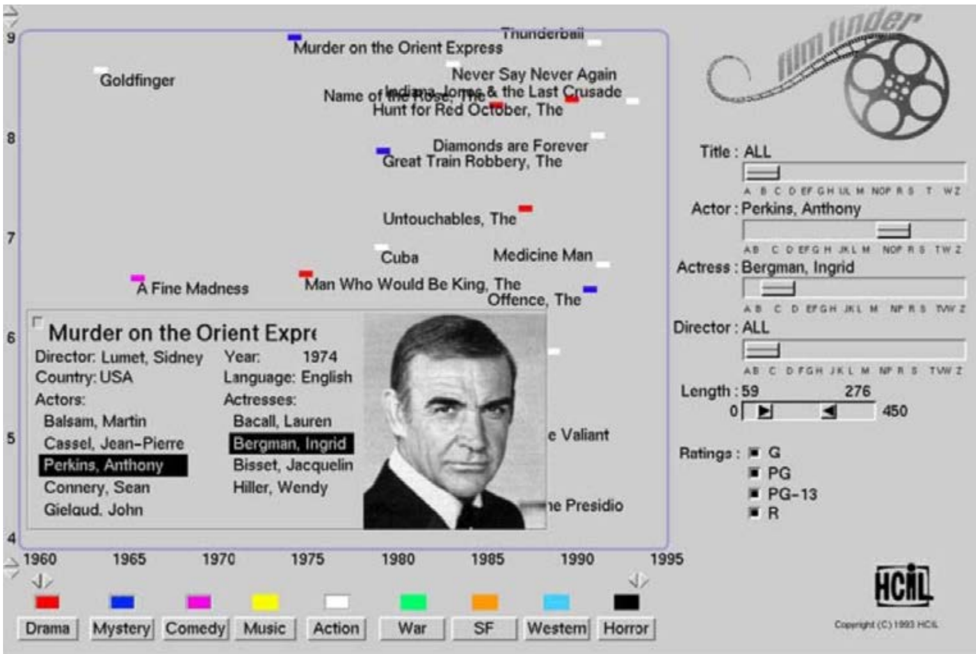

__Fig. 1.__ Visual Information Seeking, Example FilmFinder [5].

Whereas web-based toolkits exist in form of collections of measures for usability and user experience, none of them applied VIS (e.g. [6], [7]). However, those toolkits organise the measures in categories and those categories can be a useful resource to determine characteristics of measures for overview information, guiding users in the selection of appropriate measures. Reappearing category names in the web-based toolkits indicate a naming convention for groups of characteristics that could be adapted as they have a potential of being already known to the user.

Similar to the web-based toolkits, human factors (HF) related measures for the evaluation of in-vehicle devices could be collected in a toolkit. Industry and research based information about the measures could be presented with methods from VIS, reducing complexity of available information to support a decision about a measure by providing different views on the data. Each view shows the data ordered along a characteristic criterion, for example, measures required by the NHTSA guideline. The principle benefits of applying VIS in this context are to introduce users to new measures and engage users to apply measures they have not previously used. This has the potential to lead to extended insights for product improvement.

This paper presents the development of a novel conceptual interface for HF related measures in automotive industry, in the following called HF toolkit. It is developed for, and in collaboration with, an industry team of automotive HMI practitioners to support the selection and comparison of HF related measures for user studies evaluating in-vehicle devices. The development started with an investigation of the criteria that practitioners in automotive industry use to decide about the suitability of those measures (Fig. 2). Those criteria were then implemented in a VIS based interface. The interface was iteratively improved with practitioners in four paper prototyping studies. The HF toolkit can be adapted to other automotive HMI teams, and research teams in that area. Whereas the interface is in general applicable to HF related measures for evaluation of in-vehicle devices, the research arguments in this paper use examples from the distracted driving domain.

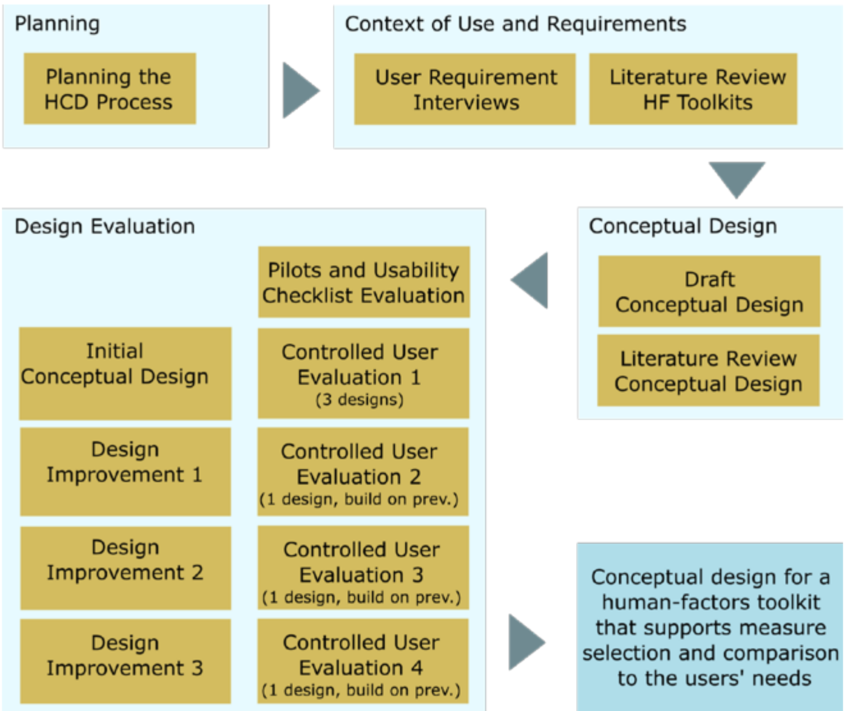

Fig. 2. *The User-Centred Design Process of the HF toolkit.*

2. Understanding Measurement Selection in an Industrial Context

The first step of the HF toolkit development was to understand how practitioners select and compare measures. Three Human-Machine Interaction (HMI) practitioners from automotive industry and two managers of an industry HMI team volunteered to participate in a semi-structured interview, lasting 45 minutes and 10 minutes respectively. The interviewees completed a brief questionnaire to ensure a level of expertise with HMI. The interviewees considered themselves as knowledgeable in HMI, had knowledge about HMI terms (e.g. user study, measurement, workload, and driver distraction), and had conducted at least two HMI related studies involving workload and distraction. Guiding questions related to tools that the practitioners already used to select / compare measures, criteria they use to select measures and the expectations they would have from a new tool. The interviews were audio recorded, then transcribed into text and analysed with coding [8]. The remainder of this section describes the results.

The interviewees mentioned the research question initiating the user study as the initial and most important criteria for measure selection, but also mentioned other criteria. User evaluations can be time-critical due to project deadlines in an industrial context. An interviewee mentioned to weigh the time participants of a user study would need to complete a questionnaire against the overall time planned for the study, and other measures that are planned to be used. Consequently, the effort associated with administration and analysis of a measure and, specifically for questionnaires, the time participants need to complete the measure is important information for practitioners.

Another influence on measure selection are facilities, which are a limited resource. The location where an user study is carried out may need to be changed at short notice. For a practitioner, it is informative to know at which locations - simulator or on-road - a measure can be applied or an equipment can be used. An interviewee mentioned that in the context of eye metrics, (some) "*measurement devices weren't really developed for driving situations*".

An in-vehicle device is typically developed as part of an extended design process. When HF evaluations are integrated early on in the process, proposed design changes can be made more easily and at less costs compared to changes in the final development stage [9]. HF evaluations at an early design stage could be, for example, paper prototype studies, or focus group discussions about a conceptual idea. Interviewees mentioned that it is useful to obtain an overview of measures dependent on the development stage of the product or service.

The interviews revealed that information about the practical application of measures is sometimes missing and it would be helpful to present such information in the toolkit. For instance, an interviewee mentioned: “*I found it quite difficult to interpret my heart rate data. Because there are different filtration methods and the literature that I had did not say anything about measurements while driving*”. Practical knowledge about a measure should also include advantages / disadvantages of the equipment, how to adjust equipment to capture data correctly, how to collect data, how to retrieve data from the equipment, and a log of issues with the equipment. This vital knowledge can easily be lost if the expert for that equipment changes team or company. Provision of such information might lower the hurdle for practitioners to employ a measure they have not used before: “*If I do not know how to analyse it, it would be interesting to ask someone or to have a reference of how to analyse that*”. In summary, the interviewees agreed in principle that the toolkit should include detailed information about data collection and analysis for a measure.

Interviewees at a managerial level wished for a consistent application of measures through the toolkit. Provision of practical information as explained above would make it easier to find a shared understanding of what the measure does and how data could be reliably collected and analysed. High-quality user evaluations make it easier to communicate and convince other managers about the advantages of new in-vehicle devices, e.g. to show they are less distracting or they increase performance.

The interviewees saw the advantages of an aid in summarising literature about measures. Databases such as sciencedirect.com are valuable to look up a large set of literature, but a tool could be of advantage linking literature based on measures and specific measure characteristics, e.g. a differentiation between studies that collected eye metrics with eye tracking equipment and these that used video data. Interviewees also saw an advantage in being able to compare the measures rapidly, e.g. one mentioned “*If you had only a week to do an assessment, is there a quick one that you could do, like weighting pros and cons …*”.

The toolkit’s information categories and structure focus on the following use-cases, derived from the expert interviews: exploration of measures, a quick overview of a measure, quick comparison of measures, and information required for the utilisation of a measure (implementation, data collection, and analysis).

In summary, practitioners mentioned the following criteria as influence on the measure selection:

- Suitability to research question
- Frequency of use in research literature
- Aspects measured and utilisation in a comparable user study setting in literature
- Validity (literature or expert opinion)
- Effort to administer, analyse, collect
- Imposed load on the user
- Interference with driving
- Customised short versions of long questionnaires
- Information about implementation and analysis

3. Underlying Design Principles

People often have difficulty to retrieve a particular information from a large volume [3]. The variety of information about a measure and available options of measures can lead to a high information load during the comparison of measures. Information overload can be reduced by the information seeking mantra: "*Overview first, zoom and filter, then details on-demand*." ([3], page 2). Fig. 3 shows how information for measures of relevance to this paper should be presented according to the mantra. Recommendations for the toolkit and criteria by which practitioners select measures were extracted from the interview transcription, and used as a base for the creation of an overview information that users can select to retrieve and compare measures in the database. The following paragraphs explain each step of the information seeking mantra.

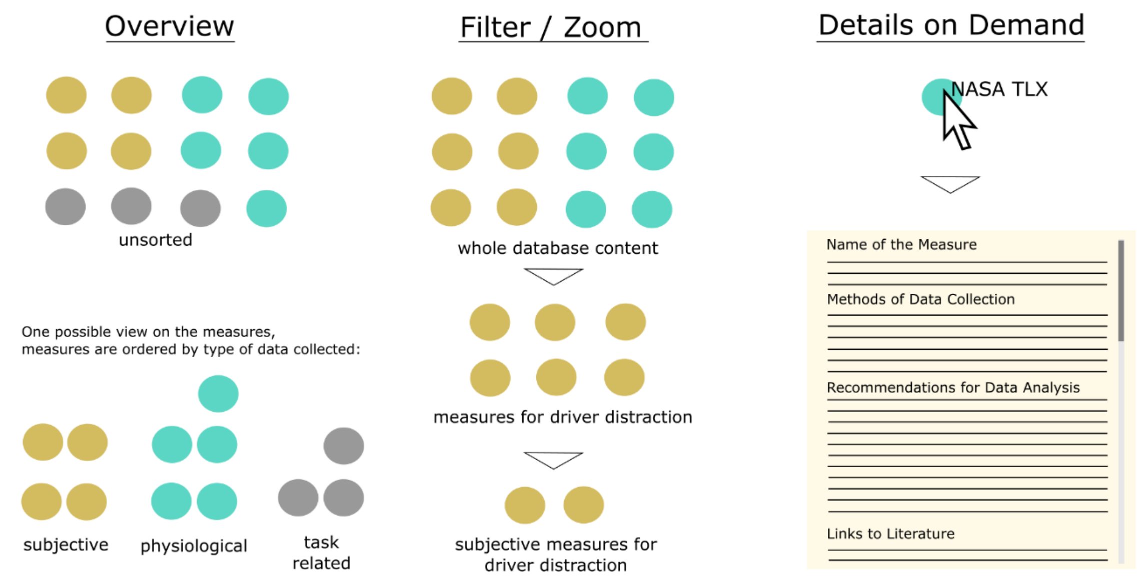

Fig. 3. *The Steps of Information Seeking According to the Visual Information Seeking Mantra.*

Overview information

The overview shows the whole content of the HF toolkit by a characteristic of the measures [3]. Users can select views on the dataset. In each view the dataset is sorted along a certain characteristic criterion (e.g. the type of data collected with a measure). Every dimension describing a measure could be a potential view offered to the user, to examine the dataset in the overview, such as, quality, practicability, and the environment they can be used in. VIS literature suggests that views in the interface should represent those characteristics of measures that best support users in their task of examining the data in order to find a suitable measure for their planned evaluation [10].

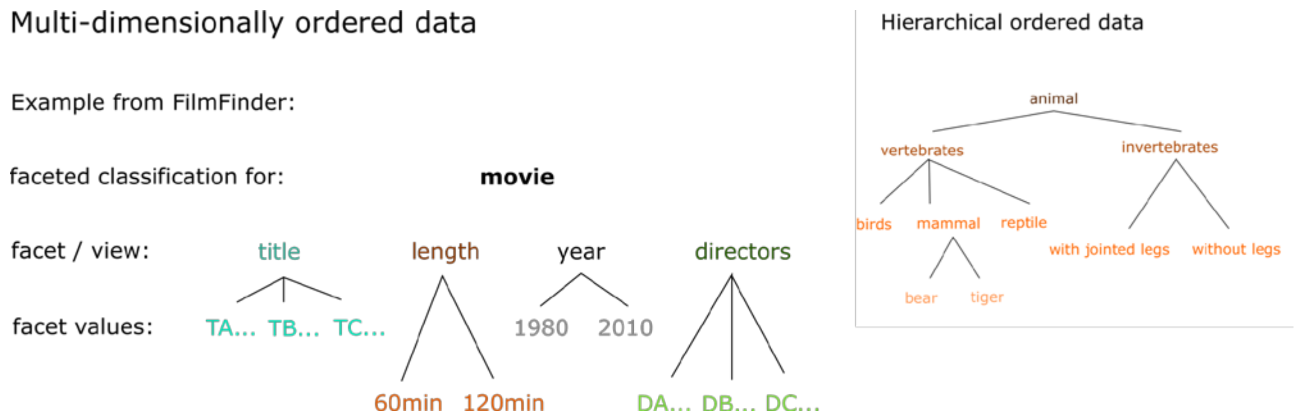

Fig. 4. *Hierarchical Ordered Data compared to Multi-dimensional ordered data.*

Faceted classifications are widely used for sorting of data in web-design. They are a set of categories to organise multi-dimensional information, e.g. socks can be organised by material, colour, or usage. Web-design provides guidance on how to organise information into facets, specifically for multi-dimensional data such as HF measures (Fig. 4) [11]. Each facet provides another view on the data, whereas a hierarchy offers one view with various levels. When a facet is selected for overview, data is grouped according to the facet values, e.g. a facet is "location of use" and facet values are "simulator", "test track / on-road" and "both (simulator and test track / on-road)". Dependent on the research question, users might be interested in different aspects of a measure. In consequence, facets should be developed related to the user's tasks. Practical information about how practitioners select measures for a user evaluation has been collected in the expert interviews and is transformed into a faceted classification in the following. A faceted classification can be developed using the following steps [12], added here with a brief description from the development of the toolkit:

1) *Collect a representative sample of measures to cover all foreseen variations*
   The sample entities were selected to cover a variety of HF related measures used for evaluation of in-vehicle devices: short questionnaire, long questionnaire, driving performance measures, driver state measures, measures required by guidelines, physiological measures, usability measures, user experience measures and measures in terms of methods that are used in early design phases (e.g. card-sorting).
2) *List measures, describe them and then summarise the description in keywords*
   The sample measures from step 1) were described including criteria from the expert interviews. Then, the descriptions were summarised in keywords. The keywords were for instance: simulator, on-road, common in literature, equipment needed, time to complete, time to administer, and interference with driving.
3) *Find terms that appear across all entities and summarise the descriptions. Narrow the terms down into a set within which all the keywords from the previous step will fit.*
   First summarising terms were, e.g. Product Design Phase, Objective, and Platform.
4) *Test ordering of all terms under the facet*
   Steps 3) and 4) were conducted iteratively, adjusting number and names of categories to those providing the most relevant information for measurement selection and comparison.
5) *Fine tune the facets with vocabulary used in the subject field*

Facet names were refined in comparison with categories used in existing toolkits (e.g. [6], [7]) and from Human Factors Engineering and Ergonomics literature (e.g. [13], [14]). Categories from the literature were, e.g. Design Phase, Product Design Phase, Information Source, Location, Method Type, Studied Period of Experience, and Information Provider. The preliminary set of facets (see Fig. 5) has been evaluated iteratively together with the visual design in paper prototype studies.

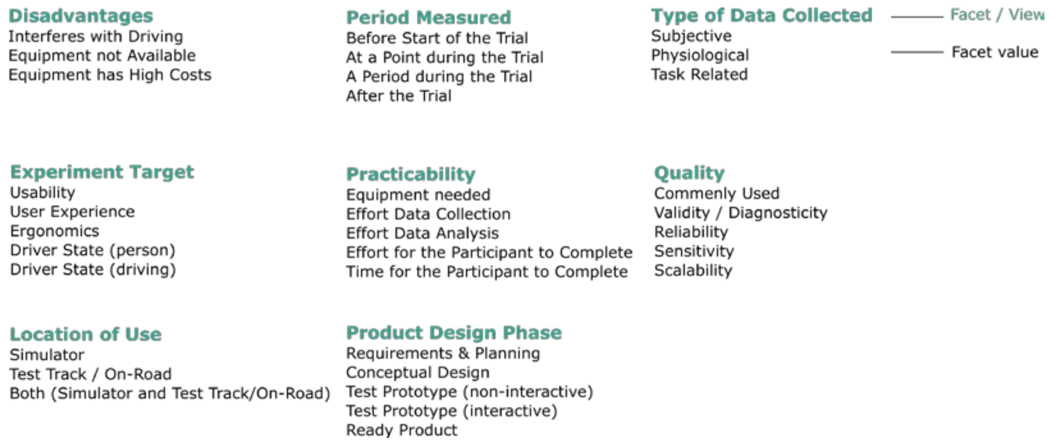

Fig. 5. *Preliminary Set of Facets (turquoise) that are Provided to the Users to Obtain an Overview of the Measures.*

Filter / Zoom

When users are satisfied with the overview information, they can apply filters to reduce the visible elements to the most interesting [3]. Filters correspond to the facets developed in Fig. 5.

Details on Demand

The users can obtain more information about a measure on demand. Following expert interviews, the detailed information should include practical information: required equipment, how to set it up, a history of issues with the equipment, and how to collect and analyse data.

Example Measuring Demand

The following section explains, through example, how measures for demand are presented in the faceted classification, and how this information can contribute to a better understanding.

Example 1

The toolkit will offer information on measures suggested by guidelines. There are different guidelines for measuring demands presented by in-vehicle information systems that suggest different measures, e.g. NHTSA suggests that the cumulative time for glancing off-road should be less than 12 seconds, JAMA suggests the total time a driver looks at a screen while completing a task should not exceed 8 seconds [1][1]. The toolkit can support users with overview information about these guidelines, what measures each guideline suggests, and an interpretation of how the measures suggested in the guideline are practically implemented, from equipment set-up to data analysis. Provision of this detailed information supports a consistent implementation and interpretation of the measures.

Example 2

Users can search for distracted driving measures and subjective data collection and find, for example, the “Susceptibility to driver distraction questionnaire” [16] to evaluate the tendency of a driver to engage in a non-driving related task. In the view “period measured” users can see that the questionnaire could be applied before and after a study. The view “practicability” will show information about how long it takes participants to complete the questionnaire. Detailed information about the questionnaire could indicate the difficulty to measure distraction directly as subjective rating [15]. Further, personalised questionnaires that have been used to measure driver distraction can be included in the toolkit and shared among the team. In fact, an interviewee did mention to use the situational awareness questionnaire to determine the demand of the alternative activity from the knowledge of the driving scene.

4. Interface Development based on User-Centred Design

The HF toolkit interface was developed along the user-centred design process, (Fig. 2), to ensure that it supports HMI practitioners in their task of measure selection. To maximise involvement of practitioners, who are bound to their industry projects, low-cost usability testing methods such as evaluation with a usability checklist and paper prototyping were utilised [17], [18]. A paper prototype interface allows users to focus on the content due to its basic layout. Sheets of paper present the interface elements and users can interact similar as with a screen-based interface. All paper prototype evaluations described in here asked the users to complete a set of typical tasks in the interface, as in [19]. Afterwards, the users were asked to rate their experience with the interface in a usability questionnaire [19].

Three HMI practitioners assessed the prototype with a usability checklist. The first three paper prototype studies comprised each of six participants, all of them automotive HMI engineers. Three HMI engineers took part in the last paper prototype evaluation. The next sections describe the first paper prototype iteration, which compared three visualisations, and then the final interface.

4.1. Paper Prototype Stage 1

The first paper prototype study aimed to evaluate if:

- the key concept of VIS, dividing information into overview and details, is suitable to represent HF measures, and
- to determine the preferred interface visualisation.

Three concepts were evaluated. Their underlying visualisations ranged from traditional to new: a well-known one adapting a spreadsheet structure (Spreadsheet concept) (Fig. 6), a known one with a diagram for comparison of information in a new context (Diagram concept) (Fig. 7), and a new visualisation presenting measures in a circular interface (Bubble concept) (Fig. 8). The Bubble concept was the most visual, but it also required the participants to think to a greater extent visually and to invest resources to adapt to a new interaction concept. Overview, filters and detailed information provided for a measure did not differ among these three concepts.

The participants completed the same set of three tasks with each concept. The tasks increased in difficulty, starting with retrieving information about a specific measure, to retrieving information about measures for a conceptual design, and finishing with a comparison of subjective measures for workload. After interacting with an interface, participants were asked to complete the System Usability Scale (SUS); rating the usability of that interface [19].

The Spreadsheet concept consisted of three large areas representing the main steps of interaction. On the top left there was the list of measures, on the bottom left were filters for measures, and on the right-hand side was an area showing favourite measures and if selected a table comparing measures (Fig. 6). Measures were listed with icons on the right side for detailed view and for favourites.

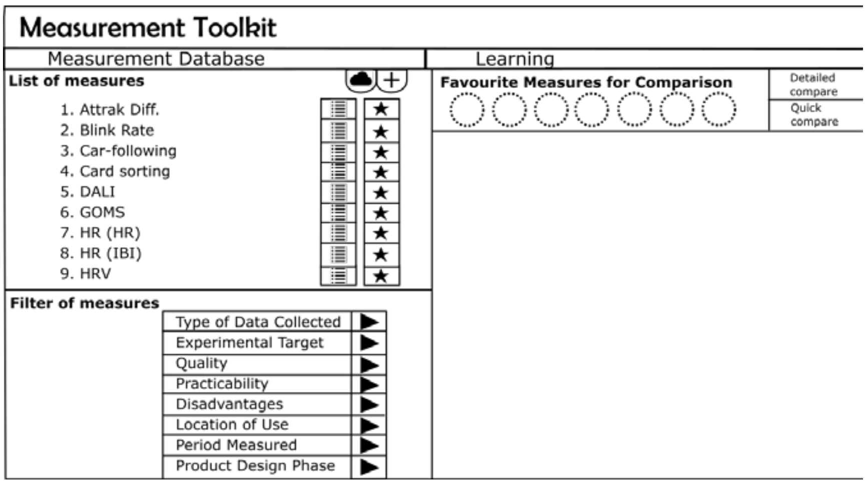

Fig. 6. *Spreadsheet concept.*

The Diagram concept applied the known metaphor of a diagram to present information in a comparable format (Fig. 7). Dots along the axis of the diagram presented measures. A measure's position along the axis was determined by its characteristic, e.g. how practical in terms of analysis and data collection it has been rated. Each tab next to the diagram provided another view on the measures, e.g. "type of data collected".

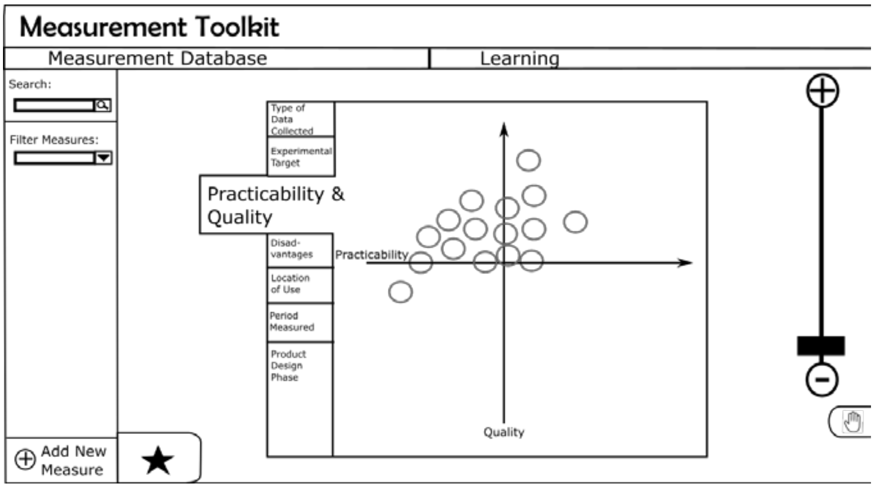

Fig. 7. *Diagram concept.*

The Bubble concept presented measures as dots surrounded by a circular menu (Fig. 8). The outer circle presented views for a quick overview, such as "type of data collected" and "practicability". The inner circle presented sub-categories for the views selected in the outer circle. With a click on a view in the outer circle, the sub-categories in the inner circle changed accordingly. If users clicked on a sub-category, lines appeared between the sub-category and each measure to which this sub-category applied. Users could also click on or hover over a measure, and then lines appeared to all sub-categories that applied to this measure.

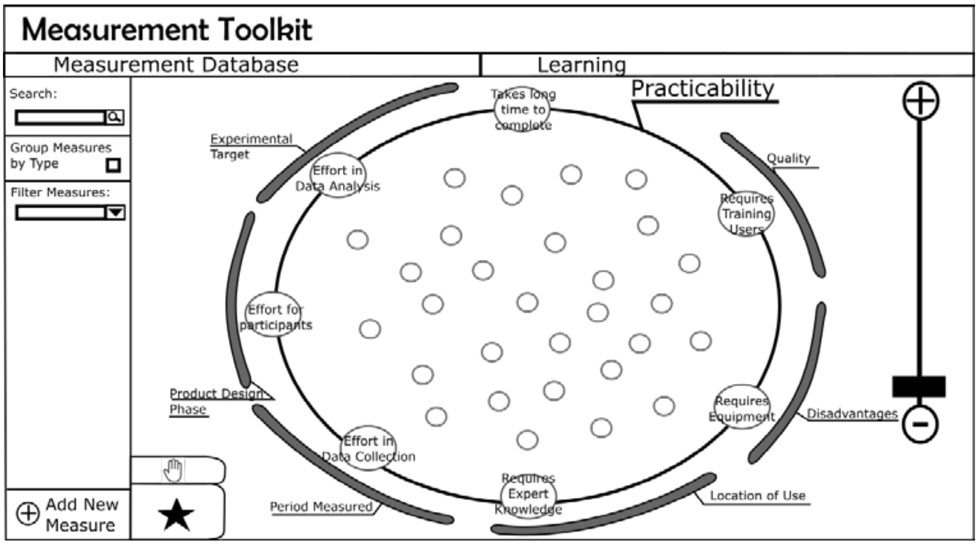

__Fig. 8.__ Bubble concept.

4.2. Results and Discussion

Six participants took part in first the paper prototype study. Each participant experienced all three concepts in counter balanced order. In each concept, participants completed the same set of three tasks with the paper prototype.

The first task included a switch between overview and detailed information whereby all participants intuitively found the detailed information of a measure. Also in other tasks, participants switched easily between overview and detailed information. This leads to the conclusion that the VIS concept can be used to represent measures in general.

However, it appears that participants prefer a known element for the visualisation and need a good structured interface. Whereas half of the participants mentioned to be attracted to the Bubble concept, four out of six participants commented that its start screen contains too much information. This perception might be influenced by the difficulty to understand the circular menu of the Bubble concept. Difficulties in understanding the Bubble concept reflected in the participants' comments. In later tasks, a higher number of participants needed help to complete the task compared to the Diagram concept, and the Bubble concept received the lowest subjective usability rating (SUS score: 53). On the contrary, participants gave positive comments about the clear structure of the spreadsheet interface, the usability was rated better than the Bubble concept (SUS score: 65). The Diagram concept, a visualisation with the known element of a diagram to present overview information about the measures, received highest usability ratings (SUS score:

76), and the least number of participants needed help to complete the tasks. In spite of this, participants made suggestions for improvements of the Diagram concept (Fig. 9). Participants quickly understood the concept of the tabs presenting different views of the data, but there were difficulties of associating a view's name with the underlying information. For example, participants did not associate study target with measures grouped into those for usability, user experience, driver performance (person), …. The participants' comments were implemented in a revised version.

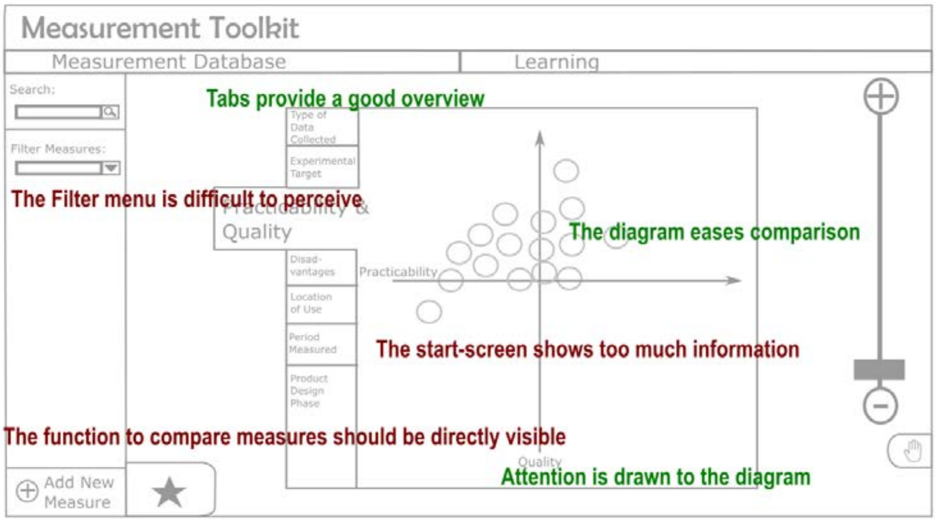

Fig. 9. *Exemplary User Comments on the Diagram Concept – likes in green, improvements in red.*

After the first paper prototype study, the Diagram concept was iteratively improved three times (*Fig. 2*). The iterations build on each other focusing on different aspects of the interface. Additionally, to the interaction-based analysis, a tree analysis was utilised in evaluations two and three to assess the effectiveness and meaningfulness of the views and filters [20]. The fourth iteration covered all aspects of the interface. Fig. 10 presents the final interface. Blue rectangles mark the main functional areas: measure comparison, information reduction, overview, and detailed information. A click on a tab of the diagram sorts the measure along that category. Tabs and filters comprise the same categories. An open presentation of filter information and colour coding, helps novice users to pick a category for overview. Measures, presented as dots, can be selected for comparison via drag and drop. A detailed comparison offers a tabular view. A quick comparison opens a new window and presents the measures in a diagram, similar as in Fig. 10.

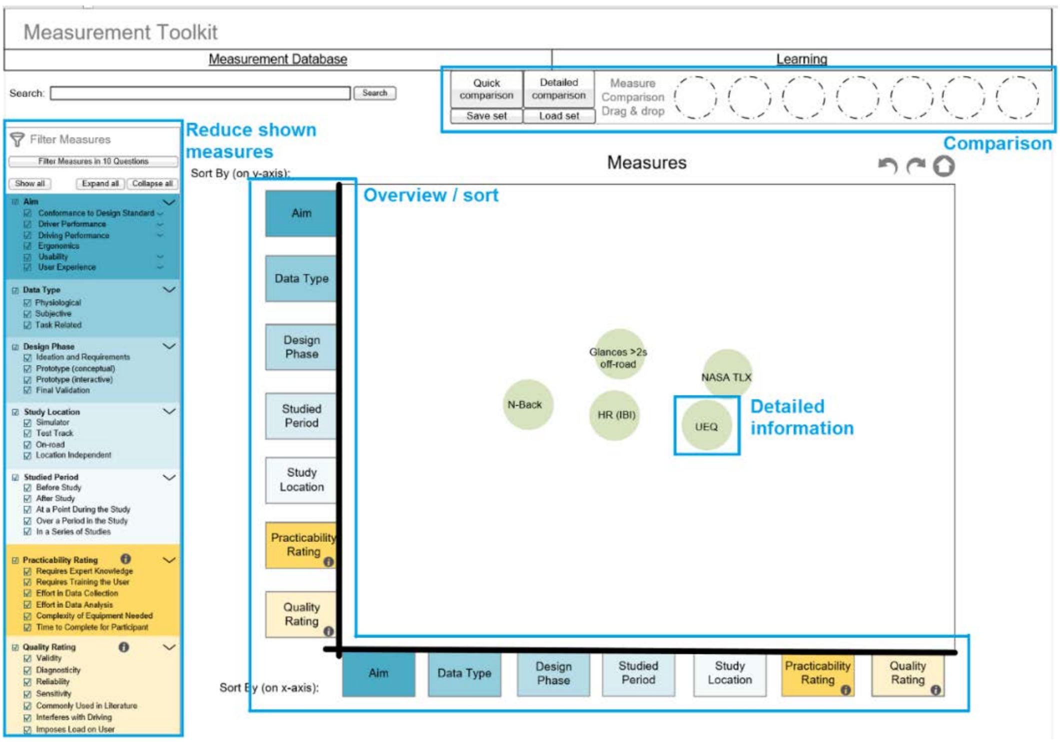

Fig. 10. The Final Interface.

5. Summary and Conclusion

The development of the toolkit presented in this paper explores methods of VIS to design an aid to support users in an industrial context with the selection and comparison of HF related measures for evaluation of in-vehicle devices. The toolkit aims to communicate information from research literature in an explorative way.

Interviews with practitioners revealed potential for the development of an electronic support system for selection and comparison of HF related measures for the evaluation of in-vehicle devices. Managers wished for a consistent application of measures and practitioners for an easy comparison of measures and integration of hands-on expertise for a measure. In these interviews, practitioners further mentioned that the decision of the measures used does not only depend on the research question, but also on the practicability of measures and the effort required for analysis and administration. At times practical information about a measure seemed to be missing in literature. Provision of this information might lower the hurdle for practitioners to employ a measure they have not yet used and will contribute to a consistent application of measures, specifically for those measures suggested in guidelines.

The user interface of the toolkit has been evaluated in four paper prototype iterations. The first paper prototype evaluation showed that VIS is suitable to present measures. Participants handled the distinction between overview information and detailed information well. A visualisation with a known element, the diagram, showed to be most effective in terms of subjective usability rating and task performance. This might have been a trade-off between users who prefer a more visual interface and users who prefer an interface with a strong structure and text.

The final toolkit will contribute to a consistent application of in-vehicle interface demand measures suggested in guidelines, such as those outlined by NHTSA. Users can perceive what measures a guideline suggests and compare them against other measures from research literature visually to select the most suitable ones for their planned study. The detailed information about a measure foresees practical information, making easy the application of measures a user has not used previously, and aids to apply measures consistently. The toolkit could further offer access to applications for data collection and analysis, functioning as a portal, which manages information around measures.

6. Acknowledgments

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