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OBJECTIVE EVALUATION OF THE COMPLEXITY OF USAGE FOR CAR INFOTAINMENT SYSTEMS

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The paper describes a measure for an objective evaluation of the complexity of usage for car infotainment systems. The method is based on the concept of cognitive complexity for computer system operation published by Rauterberg. It is shown how the psychological method can be applied to an engineering problem. Finally some results of a first investigation are presented

1. INTRODUCTION

Nowadays cars host a variety of electronic systems, which are not directly related to the driving task. These include entertainment (radio, CD-player etc.), information (dashboard computer) and driver assistant systems (navigation). In the past most of these functions were provided by separate electronic devices with their own human-machine-interfaces (HMI). Lately there has been a move towards the integration of many functions into centralized systems with a shared human-machine-interface resulting in highly integrated systems with a high complexity of usage.

The integration of the formerly separate systems, the emphasis of the visual interaction modality and the turning away from fixed meanings for keys and rotary switches (hard-key concepts) has caused a move to WIMP (window, icon, menu, pointing device) interaction modalities (soft-key concepts). These interfaces require a complex mental interaction model from the user and extensive visual attention to be used efficiently. The resulting overload of the visual canal is obvious and it can be assumed that this will cause an increase of mental workload within the user.

One can scrutinize which amount of workload respective which complexity of usage of an electronic system is acceptable and which one is desirable. Even though anybody may believe to be able to distinguish "good" from "bad" and "complex" from "easy to use" human-machine-interfaces, there is no investigation method to evaluate the complexity of usage of car infotainment systems objectively. A less subjective evaluation method compared to operator interview techniques has to be created.

The aim of this investigation is the development of a measure for the "complexity of usage" which is relatively easy to measure and compute, and which is able to predict the tendencies of people's reactions on new operation concepts in future car infotainment systems.

2. METHOD

The following concept is based on psychological work on the issue of "cognitive complexity" [Rauterberg, 1992, 1995, 1996, 1997] which originally has been developed for the evaluation of interaction complexity of computer programs. It uses a complexity measure first introduced by McCabe [1976] based on the states and transitions of a computer program. The method has been transferred to the concept of the complexity of usage of car infotainment systems.

The term "complexity" is used to describe the plurality and disorder of human behaviour [Hollnagel, 1990]. Most of the time humans tend to react to the actions of their environment [Simon, 1970, p.25]. These actions can be more or less complex.

There are several aspects of complexity involved: The observable complexity of human behaviour, the complexity of the task being performed and the complexity of the car infotainment system.

2.1 Behavioural Complexity

Besides the driving task there are several other tasks to be performed by the driver while using a car infotainment system . On the one hand he has the job to watch over the system state and on the other hand he has to be a dialogue partner to the system in order to process the given information and make decisions resulting in new system states. Taking a view on an action as a TOTE - scheme both characteristics can be assigned to one behavioural unit [Miller, Galanter & Pribram, 1973].

A behavioural unit of a user therefore consists in the easiest case of

- the aim to reach a certain state,
- the comparison with the actual state,
- the performance of an action to reach the desired state,
- the inquiry of the success and
- the end of the action.

The result is a sequence of states and transitions.

To perform a task the driver needs visual attention and manual operation. Therefore visual attention duration and manual operation frequency have to contribute to behavioural complexity.

2.2 Task Complexity

The user of an electronic system can use different approaches to solve a certain task. So the task complexity certainly plays a role for the complexity of usage. It could be calculated from the built in "best solution" for a task, which is the one the developer of the function originally thought of..

On the other hand the observable behaviour of the users has to be taken into account and cannot be replaced by theoretically postulated behaviour. It has to be asked which behaviour normally leads to a solution of the task [Fastenmeier, 1995, p.33]. Therefore it has to be differentiated between technical solutions of a task and observable solutions.

The technical solutions of a task are the ones thought of and built in by the developing engineers of an electronic system. They are the optimum.

The observable solutions of a task are the ones thought of and used by the user in a everyday context.

Only the observable solutions of a task are of relevance. Considering the fact that each solution of a task consists of states and transitions it is convincing, that non-optimized task solutions result in a higher amount of states and transitions compared to optimized task solutions.

Therefore the task complexity is estimated as the best observed behavioural complexity solving a certain task.

2.3 System Complexity

Finally the complexity of the system used influences this investigation. According to the evolution of man-machine-systems [after Rasmussen, 1983] present-day highly integrated screen-based electronic systems are on the edge from "manual regulation" to "cognitive regulation" strategies. But cognitive regulation requires a good knowledge of the system used and higher amounts of mental workload compared with manual regulation. For car infotainment systems both requirements can not be met..

Therefore car infotainment systems relying on cognitive regulation must be transparent to enable the user making the right conclusions. Among other things (hardware ergonomics; design) it depends on the complexity of the used system whether a system can be made transparent to the user. Again it has to be differentiated between the technical and the observable system complexity.

The technical system complexity is calculated from the total of functional states of a system and the realized interconnections and relationships between these states called transitions.

The observable system complexity is derived from user behaviour during the interaction with the system and considering only functions and strategies really used. All functions that were built in by the developing engineers but not used anyway are not taken into account because they do not exist in the users mental model of the system.

Therefore the system complexity is estimated as the maximum of the observed behavioural complexity of all users using the system

As mentioned before both - visual attention and manual operation - should contribute to the "complexity of usage" measure. In the concept of cognitive complexity only manual operation is considered and this is also true for the complexity of usage measure up to now. There is much hope that future work can involve eye fixation duration data, too. Thereby the connection between eye fixation duration and cognitive processes could be taken into consideration and contribute to the measure.

2.4 Definition Complexity of Usage

The fact that similarities between the operation of car infotainment systems and computers increase rapidly makes the application of methods from the field of software ergonomics viable. Software ergonomics already knows a measure called "cognitive complexity" similar to what we call "complexity of usage".

The measure "cognitive complexity" respective "complexity of usage" describes the "filling rate" of the mental model of a user compared with the complexity of a system.

"The complexity of the users mental model of the dialog system is given by the number of known dialog contexts ("states") on one hand, and by the number of known dialog operations ("transitions") on the other hand." [Rauterberg, 1992].

With a high level of complexity of usage indicating a good filling rate of the mental model of a user compared with the complexity of a system. Nevertheless comparing different car infotainment systems a low level of complexity of usage is desirable

2.5 Calculation Complexity of Usage

First the

- behavioural complexity (BC) is calculated from which the
- system complexity (SC) and the
- task complexity (TC) are estimated and result in the
- complexity of usage (CU).

The complexity of usage is calculated as

$$\mathbf{CU = SC + TC - BC}$$

with

$$\mathbf{SC = max\ BC_{total}}$$
$$\mathbf{TC = min\ BC_{task}}$$

The behavioural complexity is calculated from the number of transitions (T), the number of states (S) and a correction factor (P=1) to assure a correct result in case of a sequence (T = S ➡ BC = 1).

$$\mathbf{BC = T - S + P}$$

3. EXPERIMENTS

The experiments were conducted with 12 subjects in real life driving situations with comparable traffic conditions in the streets of Berlin - Wedding. An Audi A6 with separate HMI for radio, air-condition and navigation system served as test car.

The experimental subjects were given five tasks:

1. Tune in to a certain radio station using the search function and save it to one of the shortcut buttons.
2. Go to the sound menu, activate a function (e.g. Bass) and tune the sound (e.g.+3 dB).
3. Activate the air-condition and adjust the temperature (e.g.+2 deg.).
4. Activate the air-condition and adjust the air direction (e.g. Up only, ECON).
5. Switch on the navigation system, choose a previously saved destination and activate the destination guidance.

The experiments were run three times with each subject. To minimize learning effects the tasks varied without changing the character of the tasks (e.g. search of radio station up or down, changing of bass, treble or panning). The subjects were given their tasks directly before the execution of the experiment.

4. RESULTS

Figure 1 shows the results for complexity of usage. According to the three systems used namely air-condition, radio and navigation system there are three different levels of system complexity involved.

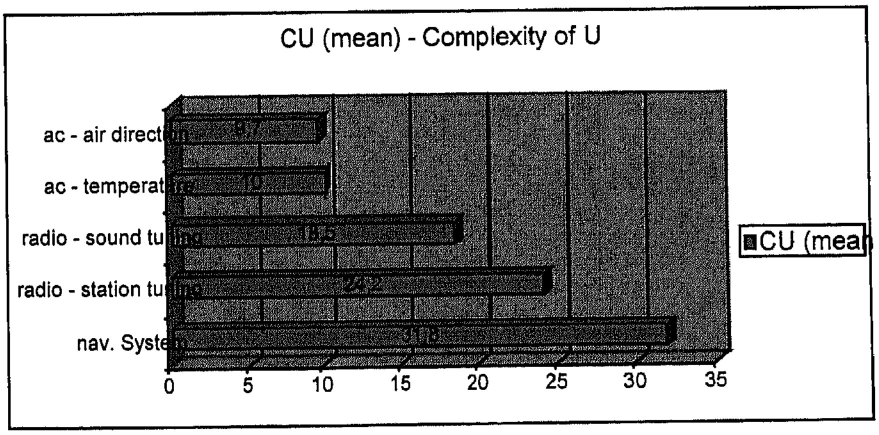

Figure 1: complexity of usage (mean)

The operation of the air-condition system was least complex, whereas operation of the navigation system was most complex. The values for the two radio tasks clearly show the influence of behavioural complexity on the complexity of usage. The radio station task was much easier to handle as the higher values indicate compared to the sound task.

5. DISCUSSION

The results allow a division of the performed tasks into relatively more and less complex tasks. Higher values for cognitive complexity within a concrete system are rated as "better" because they indicate a higher level of understanding of the system in the mental model of the user. For this reason the radio station task is internalized better than the radio sound task.

On the other side comparing the different systems there are different system complexities. If the systems were integrated in one single device, this device would have a very high system complexity due to the high system complexity of navigation systems. To compare different systems efficiently the system complexity must be of proportion with the system functionality and then should be as small as possible.

Unfortunately up to now there is no data available for a sufficient comparison of integrated and separate systems.

6. PROSPECT

The investigation applies a method from applied experimental psychology to an engineering evaluation problem. The assumptions necessary were explained and problems for future work were shown. The experiments were conducted in real driving situations and produced results that have to be evaluated in future work. The major goal of the used method is the independence from operator interview techniques. In future work also eye fixation durations will contribute to the measure "complexity of usage".

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