Automatic Parallel Parking Assistance System User Interface Design – Easier Said Than Done?

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Design of an in-car user interface requires knowledge from the field of Human Factors as well as from usability theory. In this project, a user interface for an automatic parallel parking system has been developed. The main research question has been which display modality to choose, as current literature does not give a clear-cut answer to whether to use auditory or visual displays for in-car information systems. We also wanted to investigate how much information is needed in order to complete an automatic parallel parking. Results from three user evaluations with different prototypes indicate that audiovisual presentation is best suited for the task, and that feedback messages could be kept short. However, further research is needed since a real-life traffic situation differs from that in a sealed-off environment as the one used in this project.

1 Introduction and Objectives

In order to make the driving task safer and more comfortable, considerable resources are being directed to developing systems for communication, information handling and automatic controls. Traffic information, obstacle detection, in-vehicle warning systems, integrated telephones and motorist information are examples of systems available and under development.

There has also been an increasing interest in automatic parallel parking. Parallel parking in narrow spaces is often considered a tedious and annoying task by many drivers. The situation has become even harder when visibility behind the vehicle has decreased because of aerodynamic design. Thus, there is a demand for systems that perform the parking maneuver automatically.

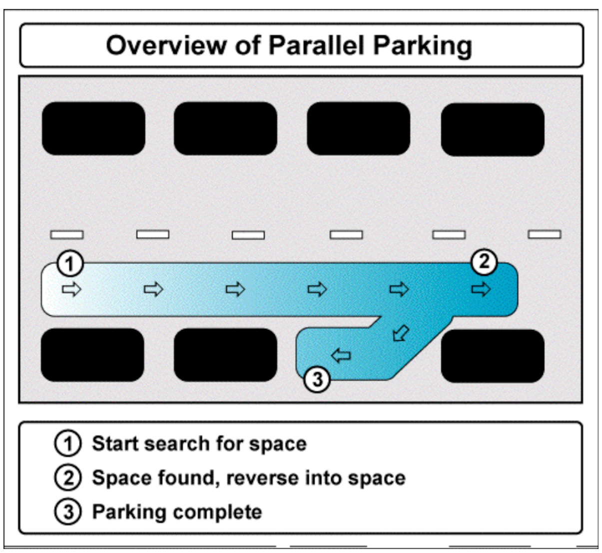

Figure 1. The parallel parking process.

Such a system is under development by the Department of Mechanical Engineering (IKP) at the University of Linköping in cooperation with Volvo. The driver activates the system when she is on a street where she wants to park. Ultrasonic sensors on the car scan the surroundings until they find a space that is large enough to park in. The system then notifies the driver. If she accepts the space, the in-car computer takes control over the electronic steering servo and the driver only has to adjust the speed and monitor the surroundings while the car automatically steers into the space and stops.

We were to design the user interface for the system, and set about doing this with a particular interest in examining the following questions:

- What modality (auditive or visual, or a combination of both) should be used for the information presentation?
- How much information does the driver need to complete an automatic parallel parking?
- How should the interface be designed to be as safe in traffic as possible?

2 Background

The rapid development in the domain of in-car technological aids has led to changes in the driving experience. There has been a history of bad designs, which have involved humans in potentially hazardous situations, and there is a risk that new demands are placed on the driver instead of offloading her.

During our work, we have studied relevant theories from the field of Human Factors as well as from usability.

2.1 Human Factors in Driving

The driving task involves continuous cognitive resources: perception, attention and motivation. Mental load in working memory, i.e. workload, and attentional resources are central parameters to be considered.

Workload is a useful measure in the assessment of effects due to the introduction of new in-car technology. High mental workload can generally be seen to increase the risk for accidents, so irrelevant information must be avoided. It is clear that a driver has bounded mental resources, and that explicit care should be taken not to tax these resources unnecessarily (Wickens et al., 2003).

The automatic parking system is expected to offload an inexperienced driver more, and we also expect a learning effect: after the system has been used a number of times, the procedure will become increasingly automated, thus placing fewer demands on the driver.

Nevertheless, if a driver assistance system is badly designed, thereby increasing the time needed to interpret feedback or make decisions, driver performance may be affected negatively and the crash risk might increase (Wickens et al., 2003). Issues concerning presentation modality and clarity are therefore of central importance.

Presentation Modes for Displays

On the perceptual level, driving is primarily a visual task, laying the main load on the visual attention system. Feedback also generally occurs through the optic channel; only a small proportion passes through others. E.g., movement can be perceived through the tactile sense and sounds may return feedback about speed or street surface qualities (gravel, asphalt etc.). Haptic feedback takes place through the perceptible positions of e.g. gas pedal and gear.

As visual cues are omnipresent in driving, there is a risk that visual display warnings may not be noticed when the display competes with demands for detection of critical information regarding the traffic situation (Stokes et al., 1990). Also, in time-critical situations drivers may be reluctant to divert attention away from their surroundings.

This leads to the idea that auditory information may be preferential. Auditory presentation can be in the form of speech or non-speech. Speech is generally seen as more irritating than discrete auditory tones, especially in cases where the informational content of speech is largely redundant (Hirst & Graham, 1997).

This could be solved by offering speech as a default option and non-speech auditory warnings as a user option (ibid.).

However, there are problems involved with auditory displays because of difficulties in hearing, noise levels in vehicle and lack of persistence, so they are therefore not always reliable.

In contrast, a different image of visual displays arises in Verway and Janssen's inferences from Wickens' multiple resource model (cited in Fastenmeier and Gstalter, 2003). They conclude that visual information in displays for navigation systems is less intrusive than auditory information, is better for self-paced tasks and also shows more practice effects than auditory presentation.

Making a decision about which presentation mode is to be preferred for an automatic parking driver interface is, consequently, not a straightforward one. The demands placed by the traffic situation, task complexity, and drivers' personal preferences are factors involved in how suitable a mode is.

2.2 Designing for Usability

The frequency of bad products in technological driver support systems must give the industry an indication: a lack of contact with users' realities gives rise to problems with design. Designers and engineers rarely share same models, nor do end-user and designers (Peters, 2004); therefore there will be differences in task perception. The designer must avoid making quick assumptions about users. This can be done by analyzing the task purpose and outcome, and users' perceptions of task limitations and difficulties. These analyses may result in ideas about how to meet the objectives of the designer and the expectations of users.

In part, these different worlds can be aligned through dialogue: interviews and observations, task analysis and user feedback.

Interface Acceptance Issues

For technical driver support systems to be successful, it is crucial that knowledge about driver behavior is applied. This concerns cognitive aspects as well as the issue of acceptance from the public. Unless designers take heed of users' confidence in and preferences for a system, new products will have little impact: drivers may simply choose to not use them.

To increase user acceptance of new systems, usability, driver preferences and expectations must be addressed, as indicated in the results from numerous evaluations (Lilienthal et al., 1997).

Apparently, drivers have individual preferences, and expect a personalized range of functions. According to Richter & Plümer (2003), drivers also demand the possibility to override any autonomous vehicle function.

Guidelines and Standards

Guidelines and standards have been developed to serve as tools and decision aids for designers. Designers must work under a number of constraints and can hopefully be aided in judging the relative importance of contradictory criteria, in order to add up to their design objectives (Mollenhauer, 2003).

Standards and guidelines in Human Factors and ergonomics are not binding. They are generally composed by specialists with true interest in the fields, but many times represent the interests of industries or nations, thereby tending to become conservative and general: they give an informed consensus view, as they must live up to the difficult balancing act of being "specific enough to give guidance, and general enough to be widely applicable" (Parkes, 1997, p. 405).

However, guidelines are not always based on or guided by scientific evidence, one reason for which is practical:

> *If a hard view of requirements for standards is taken, in which all methods tools and metrics could be demonstrated to stood the test of time and meet all the criteria of scientific validity, then (...) little progress is made.* (Ibid.)

3 Pre-Design Process

Of several available usability design models, we chose the one presented by Preece et al. (2002). The decision was based on the fact that the model is generic enough to be applied on the in-car domain as well. This process consists of four steps:

- Identifying needs and establishing requirements
- Developing alternative designs
- Building interactive versions of the designs
- Evaluating designs

Step one, identifying needs and establishing requirements, is a very important one. Results from this step are the foundation of the design work itself. Step two, the development of alternative designs, means that designers first diverge and create many different designs that should then converge into a single design suggestion. This design suggestion, in shape of sketches or similar, is then at step three developed into an interactive prototype that can be used for evaluation. The last step is the evaluation itself, where users interact with the prototype. Results from the evaluation are then fed back into step two, until usability goals are met or other factors (such as time or money) prevent the iterative process to continue.

The process of identifying needs and establishing requirements consists of a number of methods that we utilized. These will be covered in depth below.

3.1 System Description

The first step in the process of identifying needs and establishing requirements is the explicit requirements as stated by the client. If there are specific system requirements, like technical limitations, the design must be adapted to reflect those requirements. In this case, the ultrasonic sensors cannot scan the environment if the car moves with a speed exceeding 10 km/h. Also, the system is designed solely for parking spaces, which do not require back-and-forth movements to squeeze into. It only handles spaces large enough to get into with a single reversing sequence.

3.2 Front-End Analysis

In order to avoid making premature design decisions, it is good practice to lay a sound foundation for the upcoming creative process by performing a thorough front-end analysis. It answers questions such as: "How is the task performed manually? What functions should be implemented in the system?". One method of front-end analysis is the creation of a state-space diagram, SSD (Stanton & Young, 1999). It is a diagram where states of the system are exhaustively displayed in lists. The SSD helped us in finding gaps between user actions and the inputs expected by the system, thus clarifying what interaction steps and error messages needed to be designed.

3.3 Study of Similar Systems

The study of similar systems might help showing what other manufacturers have done well and not so well. We found two systems to be of particular relevance: BMW's automatic parallel parking system, to be implemented in the X5 model, and Toyota Prius' system available in Japan. The BMW interface seems to be superior in terms of demands upon attention and workload, compared to Toyota's which requires excessive interaction with the driver.

3.4 Identifying Users

We made a presumption that well-off 35–55 year-olds could be considered future users, based on the idea that income and desire for modern technology would affect choices when opting for a new car. Through explorative surveys and questionnaires, we tried to identify typical user characteristics to create personas, but the answers collected differed much. It was not possible to discriminate any major trends from the material, and therefore no personas were created.

3.5 Survey of Guidelines

In the field of human-machine interaction for in-car use, a number of different guidelines have been published in recent years, e.g. by the University of Michigan Transportation Research Laboratory (Green et al., 1993). They vary considerably as to the scope and level of detail, but they have one thing in common: they primarily concern equipment intended for use while driving at a relatively high speed, rather than low-speed maneuvering. However, we found some of the principles applicable to parking assistance systems as well. Examples of such guidelines are:

- Be consistent
- Provide support for expert and novice users of the system
- Minimize what the driver needs to read
- When dialogs present prompts or messages, design the interface so that users can interrupt these dialogs
- Keep the user informed about system status

3.6 Usability Goals

According to Preece, Rogers & Sharp (2002), usability is broken down into the following goals:

- Effectiveness (how good a system is at doing what it is supposed to do)
- Efficiency (how good it is at supporting the users in carrying out their tasks)
- Safety (how safe it is to use)
- Utility (to what extent it provides the right kind of functionality so that users can do what they need or want to do)
- Learnability (how easy it is to learn to use)
- Memorability (how easy it is to remember how to use, once learned)

We identified safety and efficiency as the most important usability goals, with learnability as an additional goal. After we had identified the goals, they were broken down into sub-goals, which in turn were prioritized. The top priority goals were:

- The driver should be able to stop the car at any time
- The driver should feel confident
- Information should be presented unobtrusively
- The number of interaction steps should be kept at a minimum
- The driver should be able to adapt the interface
- The driver should rate the system as easy to use

4 Method

4.1 General Procedure

27 subjects, 21 male and 6 female, participated in the evaluations. They were conducted in a car on a parking lot, where an empty parking space was marked with cones. No other traffic was present. Although the software for the prototypes was written to be integrated into the main computer of the automatic parking system, we used a laptop computer for presentation in the evaluations. This was because the technical system necessary was not accessible in time for our evaluations. During the evaluations the experimenter controlled the prototype manually to simulate the automatic system and respond to the actions made by the subject.

The subjects had a possibility to get familiar with the car by driving it back and forth a couple of times, after which they tested each of the prototypes once to get a feeling for what they were like. The rationale for this was that we thought that the subjects would find it easier to evaluate a prototype being able to compare it with another. Thus, they then tried the first prototype another time, and answered a closed-answer questionnaire to report their feelings and opinions about the prototype. After the subjects had finished the first questionnaire they tried the second prototype followed by another questionnaire, and so on until all the prototypes were evaluated. During all tests, the subjects' actions were recorded using a digital video camera. The evaluation ended with an interview, the aim of which was to discuss the differences between the prototypes and how they could be improved.

The order in which the subjects tried the different prototypes was varied to counterbalance the experiment.

4.2 Iteration 1

In the first iteration the following prototypes were evaluated:

- Auditive prototype containing sound signals and voice messages
- Visual prototype containing text messages and symbols presented on a screen
- Audiovisual prototype containing sound signals, text messages and symbols

Results from the first iteration showed that the visual prototype was dangerous in traffic and disliked, because the subjects had to look at the screen too much. The auditive prototype was preferred by most of the subjects, and the audiovisual was considered second best. A need for an expert mode was noticed, as the process was easy to learn and excessive information considered annoying. The subjects also thought that the voice messages were too long. Two commented on a need for making it more obvious when the automation was in control of the steering, by adding an auditive signal, similar to the intermittent beep of reversing trucks.

4.3 Iteration 2

In the second iteration the following prototypes were evaluated:

- Auditive prototype consisting of sound signals and voice messages, and an auditive signal when the automatic system was in control of the steering
- An expert mode of the auditive prototype, with sound signals only
- Audiovisual prototype with sound signals, shorter voice messages and a screen with text messages and symbols
- An expert mode of the audiovisual prototype with sound signals and the same text messages and symbols as in the novice mode, but no voice messages

Results from the second iteration showed that the auditive information was the subjects' primary source of information, but that a visual display still was considered necessary, especially due to the persistency of visual information. The subjects liked the shorter auditive messages, but the auditive signal while reversing was considered annoying and unnecessary.

4.4 Iteration 3

In the third iteration the following prototypes were evaluated:

- Audiovisual prototype with shorter voice messages, sound signals, symbols and shortened text messages
- An expert mode of the audiovisual prototype consisting of sound signals, symbols and very short text messages, consisting of no more than two or three words

Results from the third evaluation proved that the prototype and the expert mode was highly appreciated by the subjects and was not considered hazardous in traffic.

5 Conclusions and Discussion

5.1 Conclusions

Based on the theoretical framework and our own evaluations, we conclude the following:

- Feedback messages from an automatic parallel parking system should be presented audiovisually, i.e. using both sounds and visual images. The driver should not be obliged to divert attention from the road, but should also have the possibility to re-read a message she missed when it was presented.
- As the number of interaction steps are limited and quickly learned by drivers, an expert mode with less, and therefore more unobtrusive, information is needed. In general, messages could be kept short rather than complete.

Figure 2. The first screen from the final interface.

5.2 Validity and Reliability

We aimed to test which prototype the users preferred and what could be improved. How well it functioned in practice was evaluated through testing if the users managed to complete the parking process with help of the prototype, but also by figuring out if the prototype was dangerous in traffic or not. The most obvious danger would be that the driver would stop paying attention to the traffic and instead focus too much on the interface. This was evaluated through informal observations of the video recordings. The results of which prototype the users preferred have high validity. It is a subjective qualitative measure, answered by the users in questionnaires and in interviews.

The ecological validity was increased in each respective iteration. We introduced a distracting element in the form of a cyclist roaming around the parking lot (to make it more like a real traffic situation) and had increasing access to the technical parts of the car. In the third evaluation the ecological validity was dramatically increased thanks to a functioning automatic parking system. That was the closest to a real situation we could get.

As the technique for evaluation was based on the subjective opinions of the users, and was not a carefully controlled experiment, the reliability can be questioned. Still, the tendencies in the results were clear.

5.3 Fulfilling of Usability Goals

Did we meet our usability goals? Since we had no possibilities to evaluate the complete final system, we can only discuss this within the limits of the project context. Our top-priority usability goals will be discussed below, along with an estimation of whether they were met or not.

Driver able to stop car at any time

Fulfilled. The driver can stop the car by depressing the brake pedal.

Driver feeling confident

Fulfilled. Questionnaires showed that subjects felt highly confident with the final prototype.

Information presented in an unobtrusive way

Partially fulfilled. Questionnaires showed that subjects were generally pleased with the final prototype. The fact that drivers are able to switch between novice and expert mode also contributes to this goal.

Number of interaction steps minimal

Fulfilled. Under our technical constraints, we find that it would be hard to further decrease the number of interaction steps without impacting understandability.

Driver able to adapt interface

Partially fulfilled. The driver can choose between novice and expert mode. However, she cannot customize the interface in other ways, although we had plans to add a possibility to select different voices for the spoken messages.

Driver rates the system as easy to use

Fulfilled. Questionnaires and interview data confirmed that subjects considered the interface easy to use.

Figure 3. The interior of the car with the final LCD-screen installed.

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