Human-Computer Interactions: Research Challenges for In-vehicle Technology

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Biography

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Abstract

The proliferation of affordable in-vehicle technology has made the potential for driver distraction a pressing road safety concern in terms of crash risk and causation. In-vehicle technology introduces new safety and usability constraints that challenge existing Human Computer Interaction (HCI) and Intelligent Transport Systems (ITS) approaches. Too often HCI and ITS research approaches isolate the study of interactions - between human and in-vehicle computers - from the rest of activities in which the driver is involved. Our main assumption is that in-vehicle interactions activities are intrinsically linked with the setting in which they occur. Such interactions are often unpredictable and volatile. In-vehicle interactions activities arise out of a particular setting and are constrained by the very same setting. To date, there appears to have been little research examining design principles that describes how in-vehicle technology interactions manifest in the driving environment and how they can coherently blend into other drivers' activities. This paper explores research challenges that need to be addressed in order to determine how in-vehicle technology can be safely and seamlessly used in cars. We present a set of design principles for in-vehicle technology that exploit drivers' preferences, abilities, needs, physical and social settings.

1. INTRODUCTION

Human-Computer Interaction (HCI) shapes and functionalities are often limited to the intentions of the designers and their ability to anticipate and constrain users' actions (Suchman, 1987). Several theories and models have been put forward to analyze human-computer interactions (Schneiderman, 1983; Nielsen, 1993; Myers et al., 1996; Norman, 1998). The influential **GOMS** (Moran et al., 1983) model asserts that the behaviour of a person - in achieving a goal - can be rationally predicted by knowing the set of ***G****oals* (a state of affair to be achieved), ***O****perators* (acts which change users's mental state), ***M****ethods* (for achieving goals) and ***S****election* (rules for choosing among possible methods for goals). GOMS works in a predictable (rigid) environment. It does not support goal interruptions process, errors or more improvised type of behaviours that characterize driving tasks.

Interactions with in-vehicle technologies are different from desktop interactions. In a desktop system, the computer is the sole point of interaction with the user. In a driving environment, the driver has multiple points of interaction due to the need to perform different tasks (primary and secondary driving tasks) concurrently and the need to be aware of internal/external events. In both cases, tasks require motor and cognitive actions. In the automotive environment, motor actions occur across distributed devices such as navigation systems, gears etc. The dimensions of interactions also vary in automotive environments. Devices such as cruise control or navigation systems interact directly with the driver whilst others such as gauges and the speedometer are mainly visual inputs that impact indirectly on driver's behavior. The nature of the drivers' tasks, the relationship between them, and the means to achieve tasks are very different for each environment.

In-vehicle and cockpit (Ballas et al., 1992) interactions have been extensively studied in the field of Human-Computer Interactions (HCI). Factors such as physiology (e.g. fatigue), cognition (e.g. overload), driver's skill, driver's ability and social settings influence the driver's behavior but have not been thoroughly incorporated in in-vehicle design studies. The large amount, the diversity and the complexity of these factors make the usability measures virtually intractable with tools such as GOMS.

The design of in-vehicle technology can benefit from sociology and ethnomethodology theories. We use social interaction theories to understand and improve human-computer interactions. Empirical methods from ethnography are also used to understand drivers' practices and experiences. Recent HCI research emphasizes using social and ethnology theories as core concepts to design "natural" computer interfaces (Dourish, 2001; Jordan and Henderson, 1995). Dourish's fundamental assumption for the design of interactive systems is that *"we cannot separate the individual from the world in which that individual lives and acts"*.

We operate with such an assumption in the context of automotive systems and high-light the implications for the design of in-vehicle technology. This paper presents research challenges for the design of in-vehicle technology. It focuses on the broader social context in which driver actions unfolds. It highlights new road safety research challenges that provide a venue for discussion between different disciplines such as ergonomics, cognitive science, social science, phenomenology, information systems, engineering and human-computer interaction.

2. TECHNOLOGY-DRIVEN CONTEXT-AWARE SYSTEMS

The main driving task consists of four cognitive decision making steps (Strauch, 2002; Groeger, 2000):

1. Assess situation: detecting changes which imply some discontinuity in currently active goals.
2. Identify the available options by appraising threats
3. Determine the costs and benefits (relative) value of each threat: a process that selects and constructs the most appropriate form of action for each circumstances
4. Select the option with the lowest cost and highest benefit and implementation of any changes in current activity that this may require.

Advanced Driving Assistance Systems (ADAS) are technologies designed to assist drivers in working through the above decision making steps. ADAS improve drivers' situational awareness and/or automatise driving tasks. In-vehicle systems that provide a complete automatization of driving tasks and/or accurate awareness of relevant information for all situations is still a vision. Although it is an active area of research, the extent to which such systems reduce road crashes is yet to be shown. The Japanese Ministry of Infrastructure and Transport estimated that ITS (Intelligent Transport Systems) could reduce fatal crashes by 36:7% and the serious crashes by 36:1%.

Research to date suggests that partial automation relieves the driver's cognitive or motor workload. However a complete automation system could lead to drivers monotony/boredom (Thiffault and Bergeron, 2002). Inaccurate situational awareness may lead to poor driver decision making but overwhelming the driver with information could also lead to cognitive overload and distraction (Brookhuis and de Waard, 2001; Chaparro et al., 1999).

The area of context or situational awareness has been extensively studied by researchers working on pervasive and ubiquitous computing (Henricksen et al., 2002; Salber et al., 1999). Context awareness systems can be used in automotive systems to inform the driver of the occurrence of relevant events for a particular situation. Such systems are also used to inform computing entities that will perform actions automatically. One of the major challenges in using context-aware systems in an automotive environment is to determine the right way to attract the driver's attention without jeopardizing the primary driving task. How attention is allocated is an important physiological and psychological problem. The role of the technology is to convey in an optimal way the appropriate information to the driver. Context-aware systems are concerned with how, when and what information to convey to the driver.

3. FROM CONTEXT AWARENESS SYSTEMS TO SOCIOLOGY

Technology cannot be the sole rationale for the use and adoption of ADAS. We argue that the design of ADAS should take into account social and ethnographic factors.

Driving occurs on the road among other road users situated in particular locations regulated by social and road rules. We cannot separate driving practice from such broader context. Indeed, driving performance is not based solely on the practical nor the physical attributes of the driving situation nor the use of technology. Driving performances involves a social and psychological process in which behavior is influenced by motives and attributes that are inferred to exist in other drivers. For example the often reported Australian phenomenon of feeling safer in a four wheel drive compared to being in a small car is a phenomenon deeply rooted in our social life. It has an impact on the driving behaviour.

To illustrate the impact of sociology on the design of technology, let us assume that during the driving decision making (step 2 in Section 2), the driver appraises a threat detected by the ADAS. The threat is conveyed to the driver as an electronic warning symbol on a Head Up Display (HUD). Such a warning might attract attention especially if the driver has never seen such a warning. If the driver would have not take any action in response to the warning with no negative consequences then the driver will assign a particular meaning to the warning. The meaning of the symbol would differ should the driver had taken another course of action.

The importance and the meaning of the symbol bears a strong social and ethnological significance. The mechanism to convey the symbol representing the threat is an important research problem. It is a technological problem which consists of choosing the right modality (sound, visual, tactile) for the right situation. However it is equally important to understand how the symbol (artifact) fits into the wider pattern of driving practice. The inclusion of the symbol in driving practice will give it a meaning as we illustrated in the previous paragraph.

3.1 Interactions are emerging actions

A physical device is an artifact often created by technologists from which human-computer interactions emerge. Such an artifact embodies a property called *affordance* that helps the user in knowing intuitively the operations offered by the artifact (Rogers et al., 2002).
There are two types of affordance

- Cognitive affordances - help the user in knowing

- Physical affordances - help the user in doing

Such types of affordance convey interactions. For example a protruding vertical door handle suggests pulling whilst a °at horizontal bar conveys pushing. The pattern of interactions is not merely determined by the physical aspect or the software embodied in the artifact. The interaction is equally influenced by and creates the social setting. In other words our social world is not only the precondition for our interactions, but is also its product. Interaction practice evolves and creates a system of meaning and value. It is important to note that the meanings and values of actions performed while interacting with an artefact are not necessarily pre-defined by the designer of the artifact. It emerges, evolves and is re-shaped constantly. The artifact and individuals have reciprocal mutual influence on the meanings. Such meanings are not necessarily universal.

The research question is how to design in-vehicle technology which has meanings that can be easily determined and molded by any drivers.

3.2 Context-awareness and interruptions

As we said earlier, ADAS can warn the driver about the occurrence of an event that requires immediate attention. An artifact exhibiting a set of affordances conveys the warning to the driver. This process can be divided into steps:

1. notification of relevant information to the driver: this is mainly achieved by technology.
2. cognitive registration of the notification (artifact)
3. understand the meaning of artifact: the meaning is created by interaction practice.
4. decision making: what to do with such information
5. switching context: implement the new activity
6. resume initial task (remember previous context)

The affordance property of the ADAS's interface should provide the means to enable a smooth execution of above steps. By smooth execution we mean natural transition that does not require significant motor or cognitive efforts.

The above steps are set in an automotive environment characterized by multi-tasking and intensive interruptions. Driving tasks must be interrupted at safe and interruptible points. We call such points breakpoints. The definition of these breakpoints depends on the driver's cognitive/motor conditions, the car and other driving environment. Once the interrupter task is finished, a recovery process should occur. A recovery process makes use of interfaces that help the driver in recalling the context of the interrupted task (Franke et al., 2002). The interpretation of the artifacts that allow interruptions depends also on the social setting and cannot be set a priori and universally.

The research question is how to build a technology that permits intensive interruptions. The order and the meaning of the interruptions as well as the recovery methods should be flexible and could be influenced by the social context.

4. DESIGN IMPLICATIONS

Drivers do not act based on universal plans but change their plans based on intensive interruption events occurring in the setting. The driver acts in a cultural, social, technological and organizational context. The phenomenological approach posits that meanings arise from actions. The meaning is created and specific to each individual. Therefore the design of in-vehicle technology interfaces should be flexible enough to facilitate such a process. Too often, by specifying how information must be conveyed, interface designers prescribe - in a rigid way - the sequence and the meaning of interactions (affordance). Such type of design should be avoided.

Given that the meaning of the information conveyed by the interface will be created and be different for each user, the interface should permit such adaptability. Making the order of human-machine interactions flexible is one way to permit such adaptability. Changing the order of the sequence of interactions will change its meaning. The user (not the designer) decides how a particular interaction fits in the wider driving practice (Dourish, 2001).

The pervasiveness of sensors and actuators in cars is likely to increase the amount of information that a driver needs to process. This information will take different forms (multi-modal information). The meaning of such information is an issue that has to be carefully analyzed. The meaning of information is not simply what is conveyed but how it fits into a wider pattern of practice (Dourish, 2001). In order to have a good human-computer design that addresses the above requirements we need to conduct empirical studies of the interaction of drivers with each other and with in-vehicle technology in the driving environment. We need to identify routine practices and problems and the resources for their solution (Jordan and Henderson, 1995). Dourish has defined design principles that take into social, cultural and organizational contexts (Dourish, 2001).

5. CONCLUSION

During the design of an in-vehicle technology, we need to challenge traditional design approaches which tend to assume that resulting interactions can be pre-determined by designers. Every instance and meaning of interaction must be accounted for separately. They are specific and situated. In this paper we highlighted contextual factors that need to be taken into account during the design of in-vehicle technology such as ADAS. The long term objective is to identify and validate models and methods for integrating safety and user-centered paradigms in software and hardware development for in-vehicle technology.

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HCI, ITS, In-vehicle design

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