A research proposal for in-car ecological interface design: to get a grip

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Abstract

Many different tasks are being performed in a ubiquitous environment as a car. The primary task is driving though with new technologies secondary tasks are affecting the driver performance in different ways. Safety is crucial and should never be influenced negative by secondary tasks. A vision of the in-car interface and the interaction with all systems or devices that are being used by the driver is that it can be seen as one environment where the devices and the different systems work pervasive and ubiquitous. The environment must support driver behavior in the future with these tasks whether they are primary or secondary, to remain the safety. In design of complex human-machine system e.g. interaction in a jet fighter cockpit, theories from Ecological Interface Design are applied to get a better understanding of how to design for such complexity where focus on one device at a time rarely occur. The ecological part is to see all the devices, interfaces in the same environment that interacts with a user as a whole. The question is; *How should one design the work domain so that a driver can be adaptive in varied situations based on the information being visualized or communicated from different interfaces in a car, with consideration to driver experience and safety?*

1 Introduction

When we are in the position of driving, there is a lot of different tasks that we perform. The primary task is naturally driving but other sorts of tasks are increasingly being performed. We use our mobile phone, our media devices, GPS-systems, and the in-car interface such as climate control. When one talks about future vehicles with sensors that will communicate with other vehicles for collision avoidance, there is even more information to be communicated to the driver. When designing for this type of tasks, much about human-computer interaction (HCI) is focused on the interaction between the user and the device or system. But in the car where driving is the primary task and the use of these devices are secondary tasks, there is a reason for looking at these devices together with the in-car interface as one united environment. The driver cannot focus on one task at hand (except driving of course) without the risk of losing attention from the task of driving. So how to create such an environment were the primary goal is focusing on driving and safety, and at the same time create/support a great user experience for the driver, not only by driving but where all the different tasks, from mobile phone use to feedback from an advanced driver assistance system, work seamlessly in a ubiquitous environment, and that it provides a correct level of feedback without negatively affecting driver performance?

This paper is a first attempt to form my research proposal about ecological in-car interface design.

2 Theoretical framework

> *"According to motor manufacturers, safety, efficiency, and enjoyment are the very fundamental drivers behind the implementation of computing and technology in vehicles. From this perspective, computing is applied to reducing accidents, increasing the efficiency with which drivers can use their vehicles and the road network, and endowing cars with qualities and features that make them enjoyable to use."*
> *(Walker, Neville, Stanton and Young, 2001, pp. 204-205)*

The environment within a car can be seen as a ubiquitous environment (Walker, Staton & Young, 2001; Henfridsson & Lindgren, 2005), where the user interface have moved from the desktop to the external world (Salvucci, 2001), and where one such external world could be an in-car interface. The in-car interface of today is moving forward to be a complex environment. It is suppose to inform, give feedback and create user experience through new media and information options for the driver and passengers, where a difficult challenge is to make these applications work together (Krum, Faenger, Lathrop, Sison & Lien, 2008). Trivedi, Gandhi & McCall (2007) talks about three main components of the overall driving system; environment, Vehicle, and Driver. From a driver perspective, the preliminary task in the car is driving. Salvucci (2006) talks about "the artifact of driving" as the relation between the vehicle and the driver and the interface in between.

In old days the few parts of the interface consisted of steering, throttle, clutch pedal and related controls such as windshield wipers, turn signals etc. (Salvucci, 2006). Secondary tasks according to Salvucci within this "artifact" includes devices such as; iPods (Salvucci, Markley, Zuber & Brumby, 2007), rich computer navigation assistance or in-car navigation systems (Takayama & Nass ,2008); (Papatzanis, Curzon & Blandford, 2007) , and mobile phones (Salvucci, 2001). Today Bluetooth technology has been implemented in many cars, and simplifies the use of mobile phones. This enables the possibility with handsfree with less affection on the driver, though the safety problem still remains (McEvoy, Stevenson et al. 2005). Another existing problem is that these kind of secondary task components are less standardized among the existing vehicles of today (Salvucci, 2006). Some systems might not be used or the demand of interacting with the different systems might affect the drivers ability to control their car safely (Burnett & Porter, 2001). This according to Salvucci et al. (2007) makes it also more important to find support for user behavior when secondary tasks are performed. A possible approach to handle these secondary tasks together with the in-car interface environment could be through Ecological Interface Design (EID) Vicente and Rasmussen (1992) and with the methodology Work Domain Analysis (WDA) (Lee, Nam and Myung, 2008). With EID an environment such as the in-car interface together with a drivers devices are identified as a whole. In EID the driver can be seen as an operator who is in control or trying to control a complex interface environment such as in the car case, where safety is a primary objective and driving the primary task.

Much focus within HCI and modeling work has been on desktop systems where now industry and research trends involving mobile devices, ubiquitous systems etc, have highlighted the importance of "off the desktop" systems. Within this category, use of interface while driving has gained attention and the problem with driver distraction as a result from in-car device interaction (Salvucci, 2004). Compared to the desktop environment or desktop system, the driver can only pay attention to secondary tasks in short moments without losing too much attention to the primary task i.e. driving the car (Rogers, Fiechter & Thompson, 2000). There are many earlier conducted studies which states that designing for this new complex system

environment create challenges and questions for the designers of in-car interfaces as more information sources are available to the driver Takayama & Nass (2008); Marcus (2004); Åkesson & Nilsson (2002); Salvucci (2001); Rogers et al. (2000). There are also many different areas where research have been done within the context of a car, for example; Driver behavior and performance (Salvucci, Markley, Zuber and Brumby, 2007), Ubiquitous environments Karvonen, Kujala and Saariluoma, (2006); Henfridsson and Lindgren (2005); Burnett and Porter (2001); Walker, Neville, Stanton and Young (2001), User experience (Mahlke, 2007), and Navigation systems (Papatzanis, Curzon and Blandford, 2007). One of few projects where Ecological Interface Design has been applied within the field of in-car interface design, is by Lee et al. (2008). In this study Work domain analysis is being used as a methodology within the theoretical framework of EID.

2.1 Ubiquitous & Calm technology

Weiser (1991) talked about a new way of thinking, where computers are part of the human world and have the ability to vanish into the background i.e. Ubiquitous Computing. Not technically but psychologically, we are not suppose to pay attention to them (ibid.). Because of human mobility, the ubiquitous phenomena must support the behavior where users moves around to keep the technology unseen and this is where pervasive computing takes place (Satyanaryanan, 2001). Pervasive computing incorporates four research domains according to Satyanaryanan;

- Effective Use of smart spaces, e.g. embedding computing infrastructure in building infrastructure.
- Invisibility, is about continuously hiding the technology from the user and let it as much as possible meet user expectations.
- Localized scalability,
- Masking uneven conditioning.

Lyytinen and Yoo (2002) explain that ubiquitous computing and Pervasive computing are different in how they employ ideas of organizing and managing computing services. Sörensen and Gibson (2006) are also doing a separation between Ubiquitous and Pervasive computing, high and low degree of mobility of embedded computing.

2.2 Ecological Interface Design

Ecological Interface Design (EID) Vicente and Rasmussen (1992); Vicente (2002) is a theoretical framework where the ecological approach to human factors is focused on the problem of how to design human computer interfaces for complex sociotechnical systems.
According to Burns and Hajdukiewicz (2004) there are three elements from ecological psychology that are beeing used in interaction design. These three elements toghether with two conceptual tools, which was an outcom from a research program conducted in the Electronics Department of Risö National Laboratory in early 1960s Vicente (2002), are fundamental parts of EID.

2.2.1 The three elements from ecological psychology

- before starting a design, the work domain must be understood cause people's actions are constrained by the work domain or environment
- Interfaces are possible to design for providing people with information which they can pick up and use
- The design of visuality for displaying information can have positive effect for a users memory and mental calculation (Burns and Hajdukiewicz, 2004).

2.2.2 The conceptual tools

- The abstraction hierarchy according to Vicente (2002) is a framework for developing models of particular work domains. A workdomain is something that you act on. The abstraction hierarcy framework can contain (depending on high or low level) two types of information;
    - low level = physical information.
    - high level = functional information.

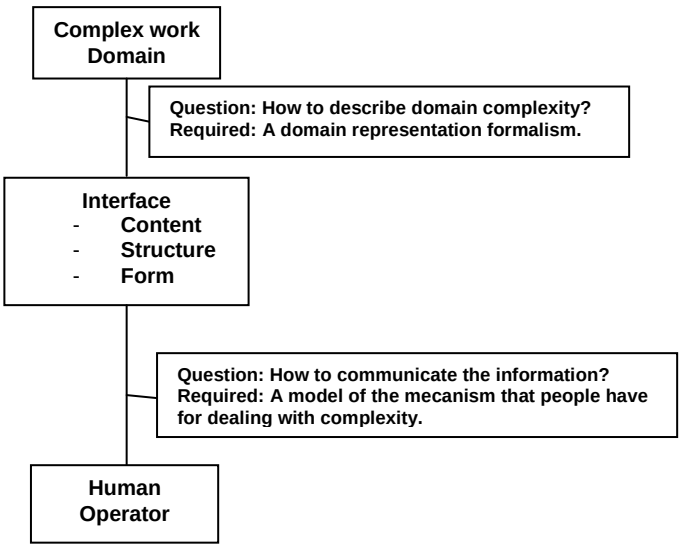
  Physical information describes the state of objects in a work domain e.g. in a car, engine, turn signals, breaks etc. Functional information describes the state of the functions that those objects are intended to satisfy (ibid.)

- The skills, rules, knowledge taxanomy (*SRK taxanomy* (Vicente, 2002. pp 64.)) describes different ways in wich users can interact whith their environment;

    - Skill-based behavior – A worker (or a driver) should be able to act on the interface.
    - Rule-based behavior – A one to one mapping between the workdomain constraints and the perceptual information in the intreface should be consistent
    - Knoweledge-based behavior – The work domain should be represented by the interface as an abstraction hierarchy. The intention is to serve as a externalized mental model for problem solving.

2.2.3 The model

According to Vicente and Rasmussen (1992) an interface is a part of a control system. This system involves human factors and machine components. When operating a control system, one has to take into consideration some fundamental constraints. A complex system for instance will require complex controllers and this complexity must be dealt with. To deal with it you need to describe the complex work domain and its constraints and for that there is a need for a domain representation formalism. The representation will describe and define the content of information and a structure of the interface. This information needs to be communicated and the required model for this is a model that can define the mechanism people have for dealing with complexity and how they process information. This is presented in the model (figure 1.) "Structure of the interface design problem" (Vicente and Rasmussen, 1992). Two questions are presented in the model and these two questions define the core of the interface design problem according to Vicente and Rasmussen.

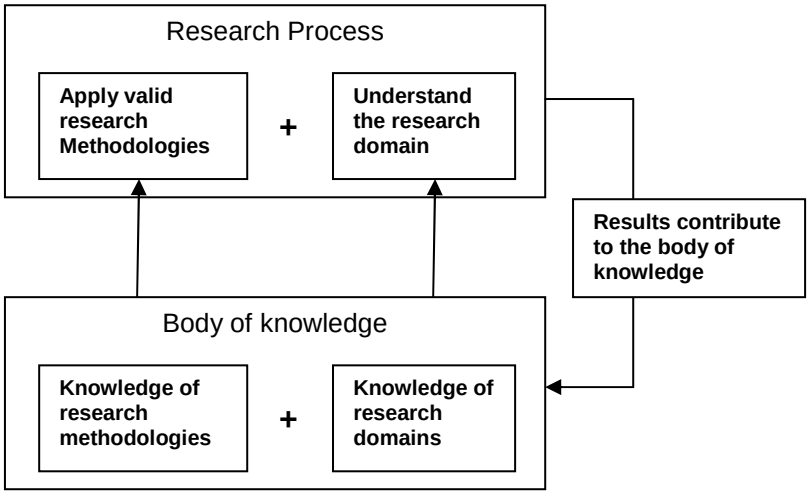


(Figure1. Structure of the interface design problem according to Vicente and Rasmussen (1992))

3 Research approach

> "*The practical question is how one should design such vehicle user interfaces that are helpful to drivers and, more importantly, do not hinder safe driving performance. Simultaneously, the theoretical question is what model predicts the kinds of responses observed from drivers interacting with computers while on the road" (Takayam & Nass, 2008, pp. 173).*

To gain knowledge of the complex environment such as the car and those tasks being performed, a good understanding of the problem space is vital (Sharp, Rogers and Preece, 2007). To understand new technology and the phenomena that surrounds it, a theoretical basis needs to be established to see what devices do, not just how they operate (Winograd and Flores, 1987). Nunamaker and Chen (1990) talks about "research domain" and "research methodology". The domain is the field or the problem that is studied in a research project. Methodology is the combination of process, method and tools that a researcher use when studying the research domain.



(A Framework of Research according to Nunamaker and Chen (1990))

3.1 Research domain

In my future research domain there are at least two main fields that I would need to understand. First, get knowledge about the car as a work domain, second to understand the user/driver as the operator who is going to perform different tasks based on information from the in-car interface. There are some perspectives in the first field that need to be considered. (i) The different types of interfaces or devices that are being used in the car. For instance, how are the different mobile devices interacting with the in-car interface i.e. can or will they perform any actions based on input/output from the in-car interface? (ii) Regardless the kind of device or interface being used there are two statements, the driver will interact with an interface and some kind of information will be presented to the driver. This leads to the next perspectives in the second field in my research domain. If a mobile device can or will perform an action, what kind of feedback should it give the driver? How will the driver perform this secondary task and if the intended task is inappropriate, how should the system inform the driver? How should the information be visualized? What type of information is going to be shown to the driver? The overall research question for the research proposal is, *How should one design the work domain so that a driver can be adaptive in varied situations based on the information being visualized or communicated from different interfaces in a car, with consideration to driver experience and safety?*
The research question is very broad I believe and will force me to break it down into sub questions. This to be able to see it from different perspectives but also for choosing the appropriate methodology and methods to use.

3.2 Possible research methodology

This section is a part that I really need to study more. I would be very thankful if I could get feedback here. I believe that I would aim at, for example interaction design science in HCI (Zimmerman, Forlizzi & Evenson (2007) but still a Living Lab approach seems interesting.

There are many different possible methodologies or approaches that could fit a research like this. A living lab approach is what seems interesting for the moment but there is others to be investigated that can be incorporated e.g. Action Research (Baskerville and Wood-Harper, 1996) (Avison, David et al. 1999) (Baskerville, 1999); (Baskerville and Myers, 2004), Interaction Design Science (Zimmerman, Forlizzi & Evenson, 2007) and Design Research (Norman, 1988); (Benbasat and Zmud, 1999); (Hevner, March et al. 2004); (Cole, Purao et al., 2005); (Jarvinen, 2007).

3.2.1 Living Lab

To understand the work domain, one approach that seems appropiate is to do the research based on real situations as in a Living Lab approach, where the behavior should be studied in a naturalistic living environment (Larson et al. 2005). This to develop a better understanding for design and the creation of technologies that take into consideration the complexity of life (ibid.) This kind of approach, where the findings refers to research about behaviors and persons' lives rather by statistical procedures or types of quantification, would be a qualitative research according to Strauss & Corbin (1990). A problem with classical usability research is that it is conducted in labs and not in real environments and the difference between lab and real-world results are called "ecological gaps" (Thomas And Kellogg, 1989).

3.2.2 Contextual Design

Another methodology that could be interesting to look more into is parts from Contextual design (CD) as Wixon et al. present the methodology (Wixon, Holtzblatr and Knox, 1990). The basics in CD are to support the development of products. Wixon et al. are talking about two approaches in their work; "Transform user work" and "cost effective design". It is "Transform user work" (TUW) that is the interesting part. As Wixon et al. describes it, TUW is about the understanding of the work environment and to understand what new technology brings to, and how it changes the work within this environment. It is also about the understanding of a computer system that should support those changes that new technology eventually brings (Wixon et al. 1990). There are similarities within TUW compared to what Sharp et al. (2007) for example defines as "understanding the problem space" or how different interacting systems should be seen as an environment in EID.

4 Discussion

The core idea for my research approach is to get an understanding of the environment, context and problem within in-car interface design and driver behavior. This to be able to describe a possible idea of how such an interface can be designed and what methods to use to support right decisions in the design process. If to use the EID framework, the car can be seen as a work domain, where the driver, as an operator or "worker" perform different tasks. These tasks are based on information from the interface. This interplay with a driver and the context of an in-car interface is very interesting. With a future view, there is a possible large amount of information that is going to be shown for a driver. This information needs to be visually presented and the driver must pay attention and comprehend that information to be able to adept it before making a decision. That decision will then affect the driver's ability to control the car in a possible coming collision for example. There are many discussions about how driver assistance systems can improve driver safety or not. What if the driver relies on the system too much? In what situation should the system take control over the car and when will the driver have full control? How should one design a supportive user interface in such environment?

There are still questions of what kind of methodologies to use. If to use a living Lab approach I would need to do my study in a naturalistic environment. In this case, the car is the natural environment. If to study a car in a natural environment I would need to participate with a driver and observe him/her, which directs me to methodologies that support observation and participation as key features. I would then need to create a change in this environment to be able to study if a change in the in-car interface changes the driver's behavior. For safety there might be a need for a simulator. I believe that it is important to get an understanding of the car as one environment/work domain and that will still require me to observe a driver while driving in a real car. A focus group would be interesting to use where cameras could be implemented in their cars and in that way support a more "natural" driver rather having me in the backseat observing. It is easy to end up in details so the focus should be on choosing an appropriate research methodology and that is the important next step I believe.

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