December 2004

Exploring the Impact of a Context-Aware Application for In-Car Use

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Abstract

The modern car is an excellent example of a deployed and widely used ubiquitous computing environment that allows IS researchers to actively participate and evaluate applications in this emerging area from a social as well as technical perspective. An action research project with members from the automotive industry, systems integration, and research have designed, developed, tested, and evaluated the impact of a context-aware entertainment application aimed at increasing the interaction between passengers and driver. This is a clear separation from the traditional, not only as the effort is collaborative in an industry known for its conservative and secretive in-house research and development, but also since the current innovation trend in the area is toward automating as much of the driving task as possible while supplying entertainment services to keep passengers quietly occupied. Our findings indicate that an approach where in-car entertainment applications instead are designed to create more interaction may provide new and powerful incentives for enjoyment, marketability, economically and environmentally sound driving, as well as safer driving.

Keywords: Action research, context-aware applications, innovation, lead users, ubiquitous computing

Introduction

One of the current innovation trends is to make applications (particularly mobile) adapt their behavior to changes in context. Early examples of such context-aware applications include notification agents, meeting reminder agents, call-forwarding applications, and active badge systems (Siewiorek 2002; Weiser 1991). Although contextual information includes human factors, social environment, tasks, physical conditions, infrastructure, and location, the majority of applications available and studied in research use location as the only trigger for changes in behavior (Schmidt et al. 1998). In particular, the omission of social aspects of context-awareness is common (Dourish 2001a, 2001b).

Unfortunately, evaluations have primarily been conducted in artificial settings, on students or colleagues, and in environments not always similar to the intended real-life setting of the application and end-user. “The price paid for relying on simple prototypes in research settings is well known….Until real applications are tried, we do not know what is involved in making them work, or whether or not they are workable” (Grudin 2001, p. 271). In an attempt to guide the evolution of this powerful and possibly socially intrusive technology, IS researchers nevertheless need to take an active stance in the development process. “The personalized and localized nature of nomadic knowledge and computing demands an ‘up-close’ examination of phenomena as it unfolds” (Lyytinen and Yoo 2002, p. 386).

In this paper, we examine a particular context-aware application concept called CABdriver. This innovation has been developed as an action research study with members from the automotive industry as well as research. The design and development has been informed by related research on context-awareness and the specific setting of the modern car. This setting is used as the modern car already possesses the sensor technology needed, while it is also highly familiar to intended end-users of the innovation. Our research approach is comprised of elements of action research (Baskerville and Wood-Harper 1996; Susman and Evered 1978), lead user methodology (Von Hippel 1986, 1988), and qualitative interviews (Patton 2002).

The purpose of this investigation is to explore the impact of a context-aware application designed to increase the interaction in a car between passengers and the driver. With respect to the growing interest from the automotive industry to market new cars using in-car entertainment systems (i.e., backseat DVD entertainment and music systems as well as gaming consoles), design of such a system was a starting point for the action research. However, instead of the currently available solutions that pacify passengers and separate them from the driver and feeling of being in a car, this study examines whether increased interaction between passengers and the driver may be a more compelling way to go. Raising awareness and understanding of the surroundings and current driving conditions may provide new and stronger incentives for environmentally sound, economical, and possibly even safer driving in many situations, from making travel by car (as dictated by the entertainment application) more rewarding for car occupants.

The paper concludes with a discussion of the impact this application has had on five families using it in an every-day fashion over two months, focusing on three areas: (1) design implications from the specific implementation of the CABdriver concept, (2) re-examination of theory used as a guide during design, and (3) a review of the action research study.

Related Research

Context-Awareness

The notion of context remains a much debated issue. Dey et al. (2001, p. 106) define context as "any information that can be used to characterize the situation of entities that are considered relevant to the interaction between a user and an application, including the user and the application themselves." Agre (2001) emphasizes architectural as well as institutional aspects that context includes, while Benerecetti et al. (2001, p. 226) perceive a need to redefine context to better reflect distributed context-aware systems: "Context is not simply a collection of features of the surrounding environment, but a partial and approximate representation used by an agent to interact with the environment and with other agents." Alternative definitions are generally made to better fit particular aspects of research, adapted to the focus of individuals or groups of researchers and designers. Nevertheless, some efforts are emerging where underlying concepts relevant to what context is, are explored more thoroughly. For instance, Dourish (2001a) argues that the social aspect of context is not captured by Dey et al. and instead suggests that the social sciences approach as well as the technical approaches stemming from Weiser (1991) and Ishii and Ullmer (1997) both come from a mutual dependency on the concept of embodiment. Embodiment is described as having a participative status in the world and, therefore, includes physical objects as well as conversations and actions. Embodiment, from a phenomenological position, is about establishing meaning and that meaning arises in the course of *action* (Dourish 2001a). Embodied interaction is achieved when users find meaning *through* the use of the system (Dourish 2001b).

Not surprisingly, the shifting notions of context have led to applications handling contextual information differently. Most common are context-aware applications that rely on location-based data. Schmidt et al. (1998) clearly opposes this by arguing that that there is more to context than location. While retaining a technical perspective of what context-awareness is about, Schmidt et al. present a working model for context that recognizes that capturing context is about capturing human factors as well as factors from the physical environment. Human factors include the user (i.e., habits, emotions, and physical conditions), social environment (i.e., colocation of others, social interaction, and group dynamics) and tasks (i.e., spontaneous activity, engaged tasks, and general goals), while physical environment includes conditions (i.e., noise, light, and pressure), infrastructure (i.e., surrounding resources, communication, and task performance) and location (i.e., absolute, relative, and colocation).

The Modern Car

The modern car can be considered an excellent example of a widely deployed and existing ubiquitous computing environment (Walker et al. 2001). Such environments may roughly be characterized as featuring intensely integrated and contextually adapting technology that is highly user intuitive and often pervasive (inconspicuous or even unnoticeable) to the user. A modern car typically contains up to 30 onboard computers, ranging from microprocessor-controlled windscreen wipers and rain sensors to more centralized data-processing devices such as for engine management. Others interact with displays, including check-message panels to let the driver know of any problems and simple analogue gauges to show the speed and engine rpm. Enabled by global positioning systems (GPS) and geographical data stored on DVDs, navigation systems have emerged lately. More sophisticated systems include those for traction control and handling, each helping the driver to negotiate dangerous road conditions. Walker et al. (2001) outline three areas of particular relevance for in-vehicle computing: safety, efficiency, and enjoyment.

Technology addressing safety issues serves the purpose of reducing the intrinsic risk perceived by a driver. However, risk homeostasis theory (Wilde 1988, 1994) acknowledges that drivers have a target level of risk they are willing to accept. Drivers compensate for lower intrinsic risk by adapting their behavior (i.e., driving faster, braking later, cornering harder) until the intrinsic risk level meets the target risk level. It is so far not clear that increasingly automating and creating support systems for drivers reduces actual risk. A good illustration of risk homeostasis theory can be seen in the common saying among operators of towing trucks: the difference between four wheel drive cars and two wheel drive cars is that the four wheel drive cars are further off the road. This example also shows what follows when support systems are not sufficient in helping the driver, as the trust in automation may lead to misuse of automations in situations with which they were not intended to cope (Lee and Moray 1992; Muir 1994). By reducing the driver from an active role to a more passive role, the driver may also be argued to be less capable of handling a situation where supervisory control systems are unable to help sufficiently (Reason 1990).

Efficiency of in-car technology can be discussed on multiple levels. Aside from increasing mechanical efficiency through the integration of computing technology, it may also bring increased usability of the vehicle and the road network through support systems and navigation systems. As recognized by Stanton and Marsden (1996), the driver is gradually being relieved of control and action as technology can provide more efficient solutions. This shift from local manual control to supervisory control raises important human factors issues. First, driver mental workload (Stanton and Young 1998) becomes a paradox as new technology may increase as well as decrease workload. Under normal operation, support systems provide great assistance in retaining the feel of relaxed and controlled driving. However, handling situations where their limits are exceeded becomes excessively difficult for the driver who until that moment likely was unaware of how dangerous the situation had become. Second, it has been argued that it is important to be as direct as possible to enable effective driving (Welford 1968), while others stress knowledge of results as more important (Annett and Kay 1957). In either case, drivers need efficient feedback from the car and its environment in order to continue driving with the same relative ease (Stanton and Young 1998). Finally, mode awareness (Stanton and Young 1998), also known as situation awareness (Endsley 1995), is closely related to feedback but refers to the ability of a driver to effectively create accurate mental models of vehicle state and the current environment, using the feedback received, in order to predict future states. This process, therefore, bears much resemblance to embodied interaction discussed earlier (Dourish 2001a, 2001b) and thus relates closely to the definition of context-aware applications we are using.

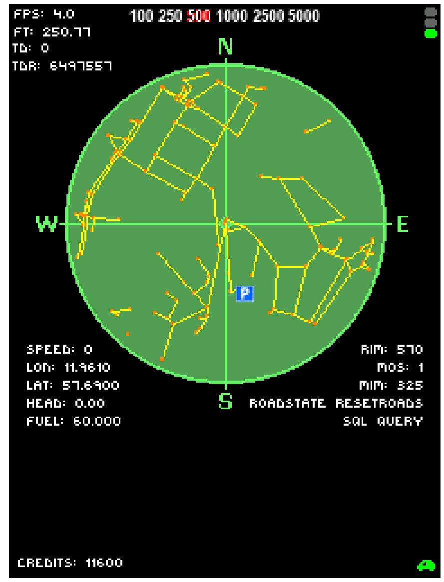
Enjoyment is one of the primary aspects used for marketing cars. Nevertheless, while car advertisements typically show empty roads, freedom, leisure, comfort, and safety, research continues to view car travel as a dangerous, stressful, and unenjoyable activity in which the human element is the cause of accidents (Stanton and Marsden 1996; Walker et al. 2001). Jordan (1999) argues that quality of feedback interacts with usability; this interaction in turn interacts with the driver's perception of enjoyment when using the car. However, challenges when driving (i.e., making it harder) may also bring more enjoyment to driving (Walker et al. 2001), thus illustrating how increasing risk in driving can be done quite on purpose.

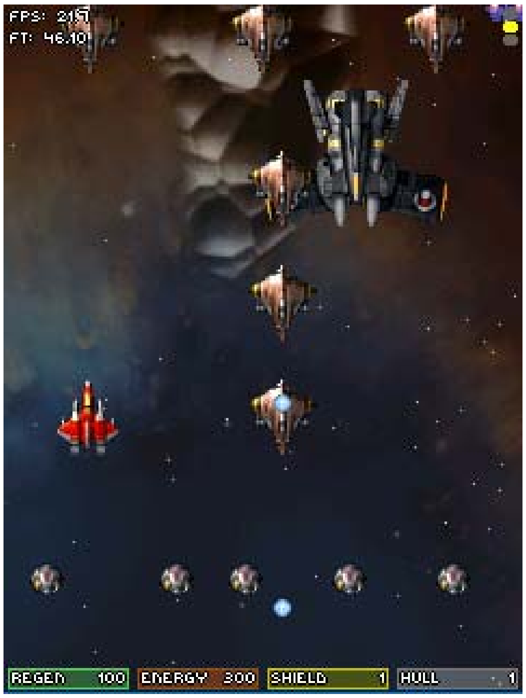
For us, using the car provides us with a highly developed and widely deployed environment for every-day evaluation of context-aware applications by potential end-users in a setting already familiar to millions of users across the world. Below we provide an outline of the particular application we are using. Currently, it focuses primarily on enjoyment although it contains elements of safety and efficiency as well. It may be noted that we are expanding the meaning of enjoyment, as it is discussed by Walker et al. (2001), since they have a driver focus while ours includes passengers as well.

CABdriver

The application evaluated and discussed here is the first implementation of the concept CABdriver. It is a hand-held game that uses input from a moving car and its surroundings to affect the game itself. However, setting the limits of an application to the technological artifacts and contextual information affecting it would omit the social aspects of context and context-awareness. From a strictly technical point of view, there is a multitude of influencing data supplied to the game through the car that is used to create *context-adapted* behavior. To expand on this, CABdriver has been designed to stimulate interaction between the player and the driver. This is done by having the game become significantly harder from aggressive driving (i.e., excessive speeding, high fuel consumption, hard braking). The player and her interaction with the driver are thus an important part of the CABdriver concept, which also further explains the name—Context-Aware Backseat driver. To stimulate the driver perceiving value by having someone play CABdriver, the application contains (and is affected by) information such as traffic messages (i.e., accidents, hazards, road obstacles), geographical points of interest (i.e., gas stations, restaurants, parking spaces) and warning systems from the car (i.e., traction control system, electronic stability program, anti-brake locking). By communicating information that may be of relevance to the driver, the player has an important role in making CABdriver truly context-aware. CABdriver does not become meaningful unless the player and driver are able to associate the information affecting the game with the real world and use it to adapt their behavior accordingly.

The game itself can be described as a relatively straight forward shoot-em-up with added tactical elements. The screenshot on the right shows the radar and the road network around the car. A parking space can be seen about 150 meters behind where the car is right now. The scale is shown above the radar (500 meters radius is chosen here). By clicking the parking space, the player can initiate missions after reading about them, their level of difficulty and rewards if completed.





The screenshot on the left is from a mission as it is being played. The mid-left ship is the player, the big space-ship is the driver workload monster indicating an occupied driver, the T-shaped formation of ships are enemy spaceships and the string of round balls are the result of an excessive speeding violation. Fortunately, the driver is currently driving environmentally sound (low fuel consumption) as is indicated by the full regeneration bar in the bottom left corner. This also affects the recuperation of energy spent (second from left, bottom) when the player moves her ship, shoots and needs to recharge her shield (third from left, bottom) after getting hit by the enemies. The bottom right bar shows how much is left of the hull—once it reaches zero, the mission fails. It is important for the reader to understand that the current implementation is only one way of implementing the concept of CABdriver and that a future commercial release will likely be different (although still embodying the same principles).

Research Approach

Action Research

Action research may be described as a post-positivist method for expanding social scientific knowledge while also providing hands-on value to the field studied (Baskerville and Wood-Harper 1996; Susman and Evered 1978). It is recognized as an iterative cycle of five phases: diagnosing, action planning, action taking, evaluation and specifying learning.

This particular action research study is a collaborative effort between Saab Automobile, Mecel, and the Viktoria Institute. It ran from July 2002 to January 2004. The initial diagnosing phase was driven by collaborative workshop sessions with representatives of the participating organizations. During this phase, basic agreements were made as to what physical limitations (such as mobile devices) and what development tools would be most efficient to use. While the industrial parties provided feedback from previous research and development from their part, the Viktoria Institute conducted a two-month literature review of mobile applications and development in cars and similar settings. Second, the action planning phase used this data as a guideline for specification of design and development. Third, following these design principles, each organization actively participated in the development of the integrated application concept CABdriver, focusing on their particular competence areas. Saab Automobile supplied and adapted the hardware platform, Mecel provided adaptation and upgrades of operating system as well as establishment of communication via Bluetooth, and the Viktoria Institute designed and developed the PDA application. Project meetings were held regularly to provide an overall view of progress, aside from the informal contact between project members involved in the development. Design meetings were held on a weekly basis to coordinate in-house development. Fourth, the application was tested for major design oversights by three initial lead users as well as software tested in-car by the development team during a total time span of three weeks. After this, the application was evaluated on an every-day basis by five families using their own (modified) cars over two months. All families had previous experience from evaluating prototypes developed in-house by Saab Automobile (employees from certain departments at Saab Automobile may apply for participation like this). Finally, by considering all the pieces of our action research, social and technical implications of in-car context-aware applications were outlined while the research approach used was also analyzed for strengths and weaknesses.

Lead Users

This study has used two types of lead users: one small group for the initial feedback and overall concept testing (not discussed in this paper) and one group of families with previous experience from in-car evaluations (see the next section). The lead user methodology was established in the 1980s by Eric Von Hippel (1986, 1988) and revolves around carefully identifying and selecting users particularly skilled at assessing innovative new technology. Contrary to traditional users, who have strong tendencies to use new technology in the same way as similar technologies with which they already are familiar, lead users hold predictive and imaginative powers that enable them to see beyond the traditional and established ways of using and thinking about an innovation. Therefore, "lead users who *do* have real-life experience with novel product or process needs are essential to accurate marketing research" (Von Hippel 1988, p. 107).

Rather than adopting a more quantitative approach to finding lead users (Von Hippel 1988), we have taken a subjective approach. First, the Viktoria Institute hand-picked three individuals to use as initial lead users during the latter part of test and development, based on extensive experience from dealing with them in other contexts. Second, five experienced families were selected from those Saab Automobile have used with great success in similar innovation evaluations prior to ours. It is the results from these five families we are reporting on in this paper. All lead users participated on a voluntary basis. Traditionally, lead users have been used in surveys, scenario discussions, and similar brainstorming activities, rather than being able to actually use the technology. As our lead users were exposed to the innovation, we expect this to improve the validity of our results significantly. However, it is important to remember that this study is an in-depth study rather than one focusing on finding generally applicable results. The discussion of implications, therefore, describes, speculates, and argues, rather than "proves" any particular hypothesis.

Evaluation Strategy

Five families were studied in their use of CABdriver from early November 2003 to early January 2004. Data was collected at two points of this period—midway through and at the end of it. We encouraged participants to explore and use CABdriver *as they themselves saw fit*. A 2½ to 3½ hour long recorded semi-structured qualitative interview (Patton 2002) halfway through the evaluation represented the first data collection point. Questions were formulated to encourage all family members to answer and asked for scenario descriptions of incidents they had experienced in the car. They ranged from appropriation questions (i.e., types of use and misuse, attitudes, conflict management, participation, changes in behavior, experimental use) to questions relating to their views on travel by car with and without CABdriver, their expectations of what long-term use of CABdriver would mean for them, the future of the application concept and their views about being a part of the study. The second data collection point was designed as an open-ended questionnaire that was developed based on the results from the first data collection point. It consisted of 27 questions that most families had discussed in the first interview. This questionnaire was answered in writing—one questionnaire per family—and followed up on how CABdriver had been appropriated, their perception on travel by car during this time, the long-term feasibility of the concept, possible future directions to consider implementing, and their feelings about being a part of the study. The questions were open-ended and again designed to stimulate participants to describe examples from the use to support their opinions. Throughout the study, the participants showed a large degree of commitment and sincere effort was put into critically assessing the implementation (likely stimulated by their previous experience from evaluating in-house innovations).

The families have been numbered 1 to 5. Data collection point one allowed for individual answers, and is denoted with first name and family number. Data collection two only allowed for group answers and is thus denoted only by family number. Each family contained two adult drivers (one male and one female) and at least one frequent passenger (any gender or age). Although the families contain a mix of female and male drivers, passengers, and children, gender difference was not an object of investigation at this point. Families were selected based on (1) frequent use of the car and (2) varied length of travel by car with at least one passenger. Hardware and software requirements for integrating the application with the car also required participants to have a Saab 9-3, as well as be willing to have in-car hardware and software adapted (and in some cases installed).

An In-Car Evaluation

The collected data has been divided into three categories: (1) a positive stance toward the application concept; (2) social impact through increasing interaction, influencing behavior, and increasing understanding; and (3) exploration of application boundaries. This categorization was not intentionally made prior to evaluation, but rather what emerged through the use of CABdriver.

A Positive Stance to the Innovation

All families left the evaluation with a positive view of the application concept. Upon returning the hardware and software involved in the evaluation, the families expressed to a varying degree that they would miss being a part of this research.

> So you don't think we should return it? (Inger, Family 1)
> NO!!! (Christian, Family 1)
>
> [It] has happened that they [the children] want you to take an extra ride when you get to where you were going. (Family 2)
>
> We prefer that something is dependant of the surroundings and the driving. You are influenced in a favorable way. (Family 2)
>
> Primary reason for arguments during use has been when two people (not only children!) have been fighting about whose turn it is to play. (Family 3, although all families mentioned this in similar ways)
>
> The only option for active driving today is to focus on time (as fast as possible) or on fuel consumption (as low as possible). More options are welcome since active driving is always better than passive driving. (Family 4, about being willing to adapt their driving on a permanent basis to an application such as CABdriver)
>
> When you come home you stay in the car and play for 15 minutes. (Thomas, Family 5)
>
> We think it is a good idea to connect game and driving in a way that is promoting responsible driving. The connection to the car gives an additional dimension to the game that traditional games don't have. [This] increases the communication in the car even though someone is almost 100% concentrated on a game. (Family 5)

Only Family 3 experienced problems with this particular implementation of the CABdriver concept as their two sons both suffered from severe motion-sickness and, therefore, could not play the game as much as they would have liked while the car was moving. Value was perceived as gained by drivers and passengers by using CABdriver, even though it is still early in the innovation process (this being the first completed implementation, rather than a commercial version).

Social Impact

The use of CABdriver highlights social impact on three levels. First, the interaction level clearly increased within the car. Second, group members (driver and passengers) show a willingness to adapt their behavior when they better understand the context. Third, an increased understanding for the roles of other group members can be seen as resulting from the use of contextual information. Increasing the opportunity for interaction has resulted in more active passengers as well as drivers.

> It came in harmony from the back: "you are driving too fast!" (Inger, Family 1)
>
> There is more interaction when you have the game than when you don't, since you become more active. Otherwise the other one mostly sits there sleeping. (Thomas, Family 5, about how the interaction spawned by the application has affected Fredrik, frequent passenger, and himself when going to and from work—both now easily staying awake.)

Interaction was generated in various situations among the families. These include:

> When unusual symbols showed up, when driving strongly affected the game, during travel in less familiar areas, [and] with little fuel left in the tank. (Family 1)
>
> When driving in the city or when you were late (time to meet), [and] also navigating in cities. (Family 2)
>
> In particular, CABdriver initiated interaction when the family was on long trips. (Family 3)

All car occupants were affected by the use and families showed signs of behavior changes varying from major to minor.

> During games [the player has] tried to stop the passing of cars (acceleration), [and] demanded reduced speed, primarily in the beginning when the player had not learned the technique to avoid the police mines. (Family 1)
>
> The children have requested a softer style of driving and that I maintain the speed limit on the highway. (Christer, Family 4)
>
> [The use] may have affected the driving without CABdriver. (Family 5)
>
> When the driver [typically] is aggressive and passes many cars on highways, the game has been relatively successful in reducing the speed. (Family 5)

Participants generally perceive children playing the game as learning the most from this implementation of the innovation concept. However, results still indicate that drivers to a large extent feel pulled into the game and thereby show a strong inclination to not only understand the player, but also to be an active part of the game.

> Initially, the missions themselves were most appreciated by the players, but later to be able to affect driving and navigation was most rewarding. For the driver, it was most liked because your driving could affect the difficulty of the game (I have become a wiser, more aware driver). (Jan, Family 2)

Sometimes, this pull is so strong that small conflicts or hazardous driving may be the result.

> When do your parents not listen to your requests for them to drive more carefully? (Researcher)
> Sometimes... when they want to tease [us]. (Viktor, Family 4)
> Or maybe it is because they have to brake! (Marie, Family 4)
>
> The player has asked the driver not to brake, for instance when driving in the city, which can become annoying for the driver after a while. You try not to brake, in order to avoid the nagging, which in turn creates dangerous traffic situations. (Per-Anders, Family 3)

Family 1 describes that conflict could arise when the player was not doing very well with the game. At those times, it was easy to blame the driver. Additionally, the player also grew frustrated when the application occasionally suffered from poor performance or hardware malfunction, such as spontaneous crashes. At times, this made the driver force the player to stop using the application. However, no new formal or informal rules were imposed on the player although a greater need for this was noted. The increased understanding may also be used to support personal driving style preferences. For instance, Jennie describes how she used the application to supervise how fast Thomas was going, forcing him to slow down every time she thought he was speeding. She expressed a liking for having an increased awareness and a way to support her desire for Thomas to slow down some.

> I can think you are driving a bit violently sometimes, so it was good to have this [application] so I could say, "no, no, no, you have to take it easy here." (Jennie, Family 5)

Exploration of Boundaries

Boundaries of the application as well as the integration of contextual information affecting it were explored to a varied degree by the families. This included stilling the curiosity of the driver as to how the driving affected the game and difficulty level.

> It is easy as a driver to be tempted to look at the screen. As driver, you want to see how fast these inputs, like acceleration, affect regeneration [in the game]. (Thomas, Family 5)

Other comments dealt more directly with how the player-driver interaction led to the driver becoming an active player of the game even though someone else was holding the PDA. Basically, this created a multiplayer game where the driver was actively (via driving style) opposing the player, causing the original player to adopt a primarily defensive style of play, rather than actively searching out enemies to gain more points within the structure of the game.

> Quit using the turn signal or the big monster will come! (Thomas, Family 5 about Fredrik, his frequent passenger)
> Either you mess with him and use your turn signal extra, or you change lanes without using it. (Thomas, Family 5, describing his response)
>
> [As a driver] you feel that you are a bit like God. (Thomas, Family 5)

Furthermore, Family 1 realized that the game could be played outside the car as long as the PDA was not turned off when leaving the car. This enabled them to practice outside the car. After playing all missions available around the parked car, they went outside to restart the car in order to reset the points of interests. This enabled Family 1 to circumvent the unbalanced difficulty level of the early stages in the game. Family 5 achieved this in a similar way by sometimes playing the game while parked, after getting home from work.

> [Playing at home] is much easier since she always goes too fast with the car. (Christian, Family 1)
>
> It was to some extent thanks to playing the game standing still that you got enough points to afford some things. The game was very hard in the beginning. (Thomas, Family 5)

Another way to stretch the limits of what was intended with the application was to use the CABdriver radar with its road network as a primitive navigation tool. The effectiveness of this varied, some finding the radar quite useful, while others felt aspects were missing to enable proper navigation.

> Navigation help [and] information to the driver how he/she is driving [was particularly appreciated]. (Family 2)
>
> A real navigation screen is missing. (Family 4)

Exploration and expansion of boundaries not only took place within the car. On their own initiative, Family 1 went as far as to expand the questionnaire to discuss how design issues as well as game plan changes could be made for future versions of CABdriver to achieve even better results.

Summary of Evaluation Results

Both expected and unexpected outcomes emerged from the interviews and questionnaires used to gather reactions from the families. Although CABdriver as presented to the users was a functional game, the degree to which the families became attached to it and the interaction opportunities it provided were greater than expected. As hoped, use of the game did influence driving behavior, usually in a positive manner, as well as considerably raise the interaction level between passenger and driver. The feasibility of the innovation concept and the success of the collaborative effort of this action research are, therefore, confirmed. The following section discusses this in greater detail, as well as what these results mean for in-car context-aware applications.

Discussion

Design Implications from this Specific Implementation

The participants have reported positive impressions of the concept. In increasing the involvement of passengers, a new meaning to traveling by car is perceived. This implementation of the CABdriver concept may, therefore, be considered to support embodied interaction (Dourish 2001a, 2001b) and thus features not only technical but also social aspects of context-awareness. This is perhaps most clearly illustrated by Family 4, discussing their long-term willingness to change their driving behavior as they previously felt that driving only allowed for either a focus on reaching the destination as quickly as possibly, or as economically as possible. This also goes far beyond the negative meaning "backseat driver" traditionally has. By including and using information that is interesting and sometimes even vital to the driver, our context-aware backseat drivers have become an asset rather than a nuisance. The ability to provide an extended eye on the surroundings and the road network has enabled light-weight navigation and exploration of surrounding areas with which users were unfamiliar, aside from providing the player with an obvious connection between the application and the real world. Furthermore, even an early implementation such as ours has, with the aid of contextual information and social interaction, become strong enough to make Christian of Family 1 stop playing his handheld Nintendo, instead favoring CABdriver while in the car.

The current implementation still has issues that need to be addressed, particularly to insure that good driving habits do not occasionally punish the passenger using CABdriver, resulting in conflict or the driver adapting less desirable habits such as not using the turn signal. This first implementation has also had to negotiate a wide range of hardware and software development issues from being integrated with a car on a PDA. The infrastructure provided by the car is indeed highly powerful and certainly one we see as most useful to continue working with, but as cars today are only now beginning to permit the integration of user applications external to the car's dashboard, it has often been an uphill battle to identify and install the most appropriate hardware (by Saab Automobile), adapt the operating system of the infotainment system (the heart of information gathering, support, and entertainment systems—by Mecel), and set up communication and balance the application on the PDA (by the Viktoria Institute). The issue of balancing how each piece of contextual information should influence the application in an intelligible way in order to best serve the purpose of increasing interaction was a vital piece of the design, as the desire was to make the game *demand* interaction and a smooth style of driving in order for the game to be successfully played. Although the game was perceived as very hard, users and drivers found ways to deal with this by either grinding it out or working around this through exploring and pushing the boundaries of the application (as did Christian of Family 1 and Thomas of Family 5).

Another major issue for a context-aware application, intended to increase the interaction in cars, is how to balance the pull perceived by drivers to get even more involved in the game than sometimes may be recommended. We had anticipated that some drivers, at least part of the time, would not be willing to adapt their behavior and instead exercise their power over the game by refusing to interact, but we had not anticipated the level of involvement that drivers *wanted* to have in the game. From a marketing perspective, this is of course promising as the enjoyment value of the concept is clearly demonstrated, but from a safety perspective this needs to be carefully balanced. Quite likely, an even stronger cooperative element should have been designed into the game rather than many times punishing the player by making the game harder when the driver was speeding or not driving environmentally sound. This may have allowed for an even better understanding of the driver's situation as interaction would become increasingly driver-initiated rather than often demanded by the player. Interaction would still need to be two-way, as the player is responsible for navigational and informational elements such as directions to geographical points of interest and traffic messages with information such as traffic jams, accidents, and animal warnings.

Exposing drivers only to driver-related information and entertainment-related services only to passengers may sound rational, if the driver were not also human and subject to human factors and a need for social interaction. From a strictly technical point of view, we agree that a driver is more capable of driving and negotiating traffic situations if she focuses solely on this, but from a social standpoint we can observe that interaction within a car, adapted to context, increases the alertness of the driver. A strong example is given by Thomas of Family 5: previous to CABdriver, his primary passenger typically fell asleep, which also made Thomas less active and often drowsy.

Reexamination of Theory Used as a Guide During Design

In light of the duality of risk homeostasis theory (Wilde 1988, 1994), the introduction of support systems that focus solely on lowering the intrinsic risk in driving fails to address the importance of changing the *behavior* of drivers. As one way of finding enjoyment in cars stem from increasing the challenge of driving (Walker et al. 2001), it may not be a surprise that many compensate the lowered intrinsic risk level by cornering harder, braking later, and driving faster. Not only may the trust in automation lead to misuse of it (Lee and Moray 1992; Muir 1994), the move from being an active driver to a relaxed and passive driver also affects the capability to handle situations where support systems fail to provide adequate assistance (Reason 1990). Thus, a valid question at this point is: what can we do to actually change driving behavior? As enjoyment in cars also may come from perceiving a high quality of useful feedback (Jordan 1999), we may be able to enhance this to make driving feel equally enjoyable with a smoother and more safe tempo. Naturally, this is where the CABdriver concept is intended to fit in. Entertainment has already been established to be one of the strongest forces in marketing cars, but can entertainment applications also be put to other use? Below, we outline the theoretical foundation for a feasible CABdriver concept by reexamining the theory used as a guide during the diagnosing and action phases of this study.

Judging by the five families participating in this study, it appears that travel by car may become more of an appreciated social group activity rather than a necessary evil in getting from point A to point B. The next step would then be to successfully design CABdriver applications to overlap what may be considered smooth and safe driving. This is important to provide the means for useful feedback for the creation of accurate mental models to predict future driving situations, i.e., raising the awareness (mode awareness—Stanton and Young 1998; situation awareness—Endsley 1995), which would enable the driver mental workload (Stanton and Young 1998) to remain controlled. When we say *controlled*, we incorporate not only the maintenance of a level not superseding what the driver can handle, but also the maintenance of a level not *subseding* what is needed to keep the driver in an active mode. This is an important aspect as high driver workload does not necessarily mean mental *overload*. By remaining active, the driver will also have a higher likelihood to handle situations where supervisory control systems fail to help sufficiently (Reason 1990). To design CABdriver applications in a way that overlaps smooth driving is not easy, as illustrated in our design implications. For CABdriver applications to be successful in a general market, they have to negotiate the same dilemmas as other software intended for large markets. "One of the fundamental problems of system design is how to write software for millions of users (at design time) while making it work as if it were designed for each individual user (who is known only at use time)" (Fischer 2001, p. 248).

Earlier, we introduced social interaction between passengers and driver (fundamental to the CABdriver concept) as a driving force in increasing enjoyment. As in any case of social interaction, willingness from all parties to interact and cooperate is required for social interaction to be beneficial. In cases where this is not true, such as when time pressure or internal conflicts in the group exist, it is more likely that the technology will follow the same course as applications in other areas have reported on and be misused or rejected, for instance through the enforcement of rules on the use. These may be enforced in certain situations or always, as agreed upon (possibly by force) through the social interaction and likely depends heavily on the perceived mental workload of the driver. An important part of the social interaction is also to enable driver and passengers to build a shared mental model of the context (a requirement to support embodied interaction—Dourish 2001a, 2001b). This provides CABdriver applications with a major advantage in understanding driver mental workload when compared with mobile phone use in cars. In mobile phone conversations, the person on the other side can not be sensitive to the traffic situation while CABdriver users are contextually aware of the situation and may thus adapt their behavior accordingly.

A Review of the Action Research Study

From an industrial perspective, Saab Automobile believes this form of collaboration has provided them with means to break the cycle of in-house research and development that has tended to consist of reiterations of the same concepts and ideas, resulting in few significant innovations. The marketing manager responsible for the infotainment platform at Saab Automobile openly describes this as their most successful project in the nine years he has been a part of research and development. A continuation where the concept may be refined, as well as new or improved implementations may be evaluated, is being planned, illustrating a willingness to change the innovation process into one where outside collaboration may be an ally rather than a foe. Furthermore, the importance of human factors has long been known and an integral part in the automotive industry when considering new or modified car models—from the design of small details such as the rear lights to the sound of a door closing—but the CABdriver study has also shown the feasibility of a stronger incorporation of human factors in the design of infotainment services. From a research perspective, we have illustrated how theory used as a guide in the diagnosing and action phases of the research has been reexamined to form a theoretically as well as empirically founded frame for a feasible CABdriver concept. While we recognize that much work needs to be done in order to deal with the design implications, this first iteration of action research has contributed to our knowledge of designing and evaluating in-car context-aware applications.

Conclusions

This paper set out to explore the feasibility of a context-aware application concept in cars that increases the interaction between passengers and driver. The intent was to focus the discussion on (1) design implications from the specific implementation of the CABdriver concept, (2) reexamination of theory used as a guide during design, and (3) a review of the action research study. This has been done with the collaboration of an automotive manufacturer, an automotive integrator, and our research institute using a combined approach of action research, lead users, and qualitative interviews. A number of design implications were identified, ranging from difficulties in hardware and software integration to balancing the application to support smooth driving. Our participants did, however, appreciate the increased interaction between the driver and passengers and felt it was a compelling way to increase the focus of all car occupants on the driving context. Theory used as a guide in the early stages of the action research was then revisited and presented in light of the empirical findings by outlining the feasibility requirements of CABdriver applications. Finally, the action research was discussed as a success as it showed contributions to both industrial representatives and research.

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