Effects of In-Car Navigation Systems on User Perception of the Spatial Environment

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Abstract. This study aims to understand how navigation devices affect driver's awareness of the environment. The hypothesis of this study suggests that use of in-car navigation systems diverts driver's attention from outside of the car to the inside where external objects are less likely to be recognized. These objects may include landmarks, buildings, traffic signs and even pedestrians. Further, internet connected navigation devices cause the amount of information presented to user become very large in size during driving. This study conducted a multiuser field experiment in order to understand basic effects of in-car navigation systems on user perception of external world outside of the car. It was also hypothesized that technology aptitude of driver has significant contribution on how these devices affect user's perception. Results suggested that in-car navigation systems has adverse effects on external world perception. Technology aptitude of the driver played significant role on navigation device interaction as well.

Keywords: navigation system, situatonal awareness, technology aptitude, driving aids.

1 Introduction

The tremendous increase in the use of in-car navigation systems requires attenion for studying driver behaviour and way finding strategies in typical car driving task. The widely accepted popular belief is that navigation devices weaken environmental and situational awareness of driver as compared to driving without a navigational aid. There are numerous incidents where navigation devices are the main cause. In one of them, a car driver, fully obeying the orders given by the in-car navigation system, teetered on the edge of a cliff and and only could come to a stop and realized that he was in wrong path by hitting a fence [1]. In another interesting incident, a Belgian woman blindly drove 900 miles across Europe as she followed broken GPS instead of 38-miles to the station[2].

These incidents certainly not in parallel with the designs and predictions of the device manufacturers may suggest that GPS devices are incapable and disembodied understanding of the environment as Lorimer et al. argue [3]. On the other hand, some researchers believe that the use of in-car navigation systems brings new and constructive levels and opportunities into driving experience [4]. Donald Norman's

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famous “Cautious Cars and Cantankerous Kitchens” article draws attention to how an ultimate car should behave avoiding such incidents.

When there is nobody helping along, people count on their sense of orientation and past experiences. They keep the landmarks in mind, for example: “Take the first left, after the hospital”. With in-car navigation systems, this approach has been changed, and turned into listening to the device and obeying the commands it gave: “Get ready to turn left in 100 meters”. At first glance, this can be considered as a small change, but it is obvious that this situation has the potential to modify whole driving experience as can be seen in previously made studies [4-6].

1.1 Purpose

The main purpose of this study is to determine behavioral changes of driver interacting with the environment inside and outside of the car. Moreover, it is known that with different user profiles, different results are obtained as there is no unique type of driver profile[6]. Since these systems include increasing technological features in time, technology aptitude of driver is chosen as one of the variables in this study. Finding out the changes in the interaction with the environment, due to in-car navigation systems on drivers who have technology aptitude and who do not is the main purpose of the study.

First, the change in driving experience, the level of the change, and finally pros and cons of the change are investigated and studied. To this purpose, the expected outputs are as follows:

- To get general ideas of users about in-car navigation systems and positive and negative experiences that they had while using the system.
- To find out the real value of the certain features of the in-car navigation systems to the user.
- To determine the user needs, requests and expectations that can be input for device manufacturers.
- To analyze the levels of role in interaction and environmental perception of the user technology aptitude.

2 In-Car Navigation Systems

As Mark Weiser [7] foresaw 20 years ago, computers take much more place in our daily life today. In-car navigation systems, with advanced technological features can be considered as computers with features such as internet connection, backup camera, audio and video player in addition to their standard features as compass, navigation and positioning aids with a few meter accuracy [8]. According to a market research about the in-car navigation systems, by iSuppli, it was estimated that 114 millions of portable navigation devices and 57.8 millions of GPS enabled smartphones were in use worldwide in 2009 [9]. By 2012 the number of smartphone navigation application users has grown to 160 million whereas personal navigation devices totals to 150

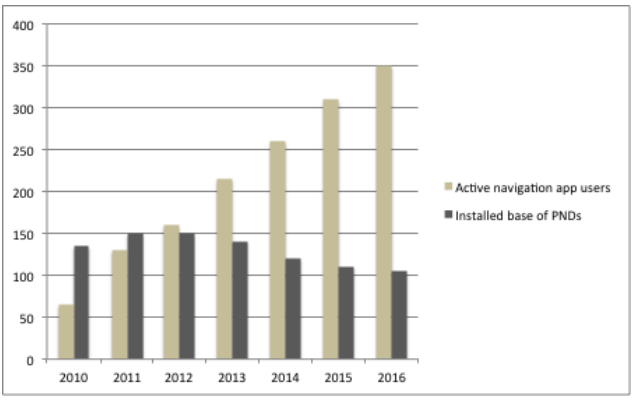

Fig. 1. PND and smartphone navigation application use worldwide (millions)

million. It is also worth to mention that worldwide smartphone sales was 700 million in 2011 with 33 million PNDs. Figure 1 shows the change of realized and estimated numbers of PND (Portable Navigation Device) and smartphone navigation applications in use.

A list of guidelines that a navigation device should have is as follows:

- Efficiency in time and mileage [5].
- Assurance of driving safety [5].
- Turn-by-turn guidance with voice instructions [13].
- Quickly accessible and easy-to-use control interface [13].
- High location not to distract driver [14].
- Delivery of valuable information such as landmarks and distance to nearest turn with voice guidance [15].

2.1 Change in External Perception

As several examples given in previous sections [1] [2], navigation products may not create the expected outcomes all the time. Guidance and routing features that are developed for the comfort of user can cause several problems due to obeying without situational awareness. Nevertheless, in-car navigation systems are perceived as an important assistant that increases safety of driver: "*I never feel like getting lost anymore*", (Participant 9). It is definite that system manufacturers have taken safety, user needs and satisfaction into consideration with high priority. However, business competition and high user expectations force manufacturers to market some features before they reach maturity. "*It led me to a closed road, I tried to find the correct road more than half an hour*", (Participant 4).

There are number of studies on the effects of in-car devices, such as navigation systems, focusing on user interaction within the environment. Horrey et al. [10]

showed in their study that as percent dwell time (the time that drivers spend looking) at the outside world decreased, the variability in lane position increased. Tsimhoni and Green [11] found out that increasing visual demand decreases the duration of in-vehicle glances, but increases their number as well as the time between them. Aporta and Higgs [12] argue that in-car navigation devices demand less skill and attention by providing orientation and navigation as a commodity, with instant availability, ubiquity, safety, and ease of use, resulting in loss of engagement with the environment and others. Their findings require particular attention since loss of engagement with environment can cause safety issues as well as problems in reaching final destination. One can immediately realize that when following friend's verbal directions, navigation devices or even following a friend's car in front, it becomes very difficult to learn the environment and find the same destination second time later. We have designed this study to investigate these factors through real life field experiments.

2.2 Measurement of User Perception

A two stage study was applied to measure the changes in user perception within the environment. In the first stage, participants were asked to fill in the survey [16], which was developed to measure their knowledge and experiences about in-car navigation systems. In the second stage, participants drove a car that was equipped by two video cameras. One of the cameras was focused on the eye of the driver, and the other camera was focused on the navigation device and the road together. Participants, who were chosen amongst friends and colleagues, consisted of 10 people of which 5 had technology aptitude and 5 did not have. Technology aptitude was determined based on participants' verbal declarations about themselves.

While the survey study helped to obtain quantitative data, the driving study made it possible to obtain both quantitative and qualitative data. Both data has been investigated, compiled carefully and divided into common groups.

3 Results

Participants consisted of mostly men (% 70) and married (% 60) people. The mean age of the participants that have technology aptitude was 32, whereas it was 55 for the participants that don't have. The general mean age was 43. Evaluations were grouped based on technology aptitude and therefore in the following figures, series names were given accordingly.

In-car navigation system usage seemed to be affected by the familiarity with the environment, as seen in Figure 2 and Figure 3. The use of PND in an unfamiliar environment for participants that have technology aptitude was % 80, whereas it was % 100 for the participants that don't have. In a familiar environment, there were some occasional usages by the participants that have technology aptitude, whereas, the other half of the participants cited that they didn't ever use it, or used it very rarely.

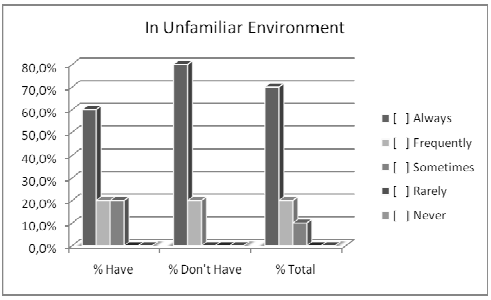

Fig. 2. Usage in unfamiliar environment

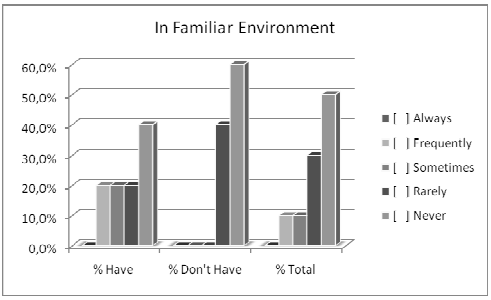

Fig. 3. Usage in familiar environment

The satisfaction of the participants about the route suggested by in-car navigation system was measured and results are presented in Figure 4. According to results, the participants that have technology aptitude are % 80 satisfied about the route and think that their personal decision and system suggestion match and so that they are convenient, whereas it's % 60 for the other participants that don't have technology aptitude.

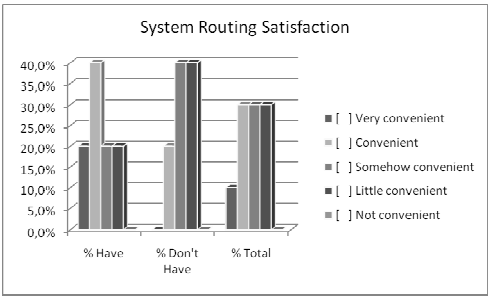

Fig. 4. System routing satisfaction

In the measurement of preferred communication method with the navigation system, participants that don't have technology aptitude preferred mostly voice communication, whereas the participants that have technology aptitude preferred both voice and display communication almost equally.

Participants indicated that the most two important features that should exist on an in-car navigation system were "Positioning" and "Route Planning" (Figure 5).

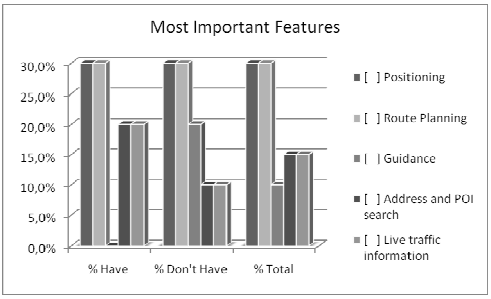

Fig. 5. Two most important features

It is clearly seen in Figure 5 that, technology aptitude is the cause of difference on relative importance of the certain PND features.

The second stage of the study consisted of a driving practice. The results of this stage are summarized as follows:

- Glances at navigation system: The participants that have technology aptitude glanced 2.8 times (σ: 0.8), whereas the participants that don't have technology aptitude glanced 1.4 times (σ: 0.5) at navigation system, mean glance number was 2.1 (σ: 0.9).
- Landmark notice: One of the most significant results of this study is the effect on landmark recall performance. The participants were asked whether they noticed 10 pre-selected landmarks. As the navigation system was on, the participants noticed 2.4 (σ: 1.2) landmarks, but as it was off, the participants noticed 1.4 (σ: 0.9) landmarks. Namely the use of navigation systems decreased the landmark recall rate by 42%.

Also throughout the experiments, following observations were obtained:

- Participant felt uncomfortable when she was led to an alley instead of highway by the system.
- It was measured that the participants that had technology aptitude looked at the system 3 times a minute, and the participants that don't have looked at the system once a minute as average.
- Participants indicated "*validation of being still on the correct route*" as the main reason to look at the device.

- Participant took the first right with the command: "*Get ready to turn right in 100 meters*". But it wasn't the right one yet. The distance perception of user is probably not matched with the navigation device estimation.
- Participant commented: "*In my navigation system the traffic message channel (TMC) support is enabled, but municipality still doesn't provide service*".
- Participant indicated that system was kind of enjoying him, and used it even in familiar environment.
- Participant was about to make an accident while programming navigation system during the drive.
- Participant indicated that using in-car navigation system prevented him from asking other people or finding on a map and so that provide a more comfortable and enjoyable transportation.

4 Conclusion

According to the results of this study we conclude that in-car navigation systems affects users perception of the spatial environment from many viewpoints. At the end of the study that consisted of two stages, survey and driving, it is observed for both participant groups that using in-car navigation system causes disengagement from the external spatial environment, being unaware of environmental objects. Furthermore, some security risk was observed due to looking at the device. It is found out that the trust of participants that don't have technology aptitude in the system is less than the participants that have, nevertheless they used it in unfamiliar environment by a high percentage. It is concluded that in-car navigation systems are successful by means of basic functionalities, but they lack support on safe driving.

Besides, additional functions such as points of interests (POI), backup camera and Internet queries of flights or weather, make the system more effective. And the system presents a social dimension and can be positioned as an entertainment tool, mostly for participants that have technology aptitude. Therefore, it is foreseen that the in-car navigation systems can provide much more than what they provide currently. With technological development they will be used by more people and will be a part of daily life.

The market shift towards navigation enabled smart phones open new opportunities for application and service providers. Extended traffic information, communication with nearby drivers, integration of search engines and online information sources along with highly skilled voice assistants will bring new ways of user interaction within the car. As these happen, measures to keep driver connected with the external spatial world outside of the car should be seriously considered.

It is also understood that technology aptitude is an important parameter that affects user perception, therefore, device manufactures can be suggested to develop customized designs for different levels of technology aptitudes according to fundamental human computer interaction principles.

It must be stated that due to serious difficulties in conducting in-car experiments, only 10 participants were participated to the study and further experiments are suggested to increase statistical significance.

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