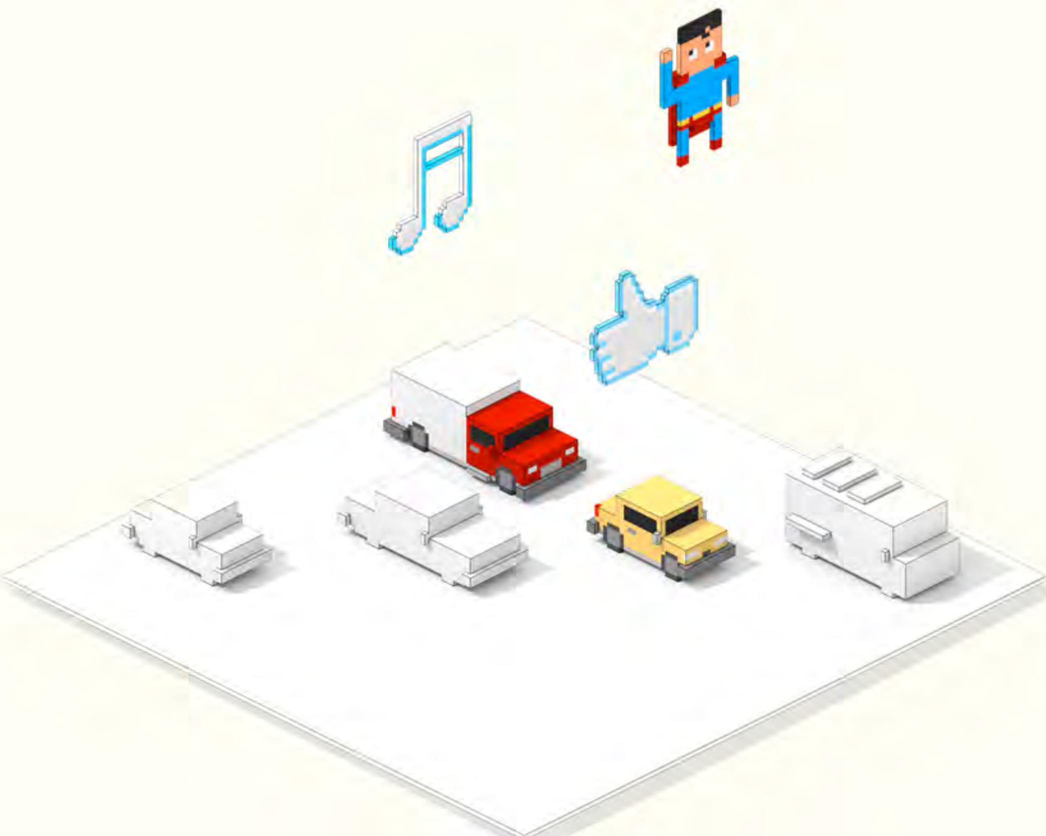
The Social Car

Enhancing Communication between Drivers by Digital Augmentation

Chao Wang



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PROEFSCHRIFT

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door

Chao Wang

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Dit proefschrift is goedgekeurd door de promotoren en de samenstelling van de promotiecommissie is als volgt:

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Contents

1 Introduction

Driving is a social activity. We need to coordinate with other drivers to share the road. However, vehicles at the same time disconnect us from the urban environment and society, fulfilling our needs of autonomy and privacy. After closing the door of a car, we are "encapsulated in a domestic, cocooned, moving capsule, an iron bubble" (Urry, 2007). Leckie suggested that cars are "semiprivate metal containers" (Leckie & Hopkins, 2002), which "reshape our public streets, sidewalks, neighbourhoods, and daily journeys". The steel shell and tinted windows of the vehicles dehumanise people (Wiesenthal & Janovjak, 1992), and the horns, indicators and car body language become the only tool to coordinate with other drivers. As a result, car-traffic allows people to "mix and assemble without ever meeting", as described by Lefebvre et al. (Lefebvre, 2000, p.101):

> *"Motorised traffic enables people and objects to congregate and mix without meeting, thus constituting a striking example of simultaneity without exchange, each element enclosed in its own compartment, tucked away in its shell; such conditions contribute to the disintegration of city life."*

In general, the limitation of communication and the anonymous relationship between drivers lead to two major problems: conflict in sharing the road and social isolation while driving.

Normally, people encounter large numbers of other vehicles during a trip and need to negotiate with them to share the road. However, the negotiation is not always successful. In the last decades, the term "aggressive driving" has appeared in many papers and media. It may be defined as "any driving behaviour that intentionally endangers others psychologically, physically, or both"(Ellison-Potter, Bell, & Deffenbacher, 2001), which ranges from hostile horning, rude gestures to tailgating, cutting off and even shooting at others.

According to the 1998 British Crime Survey, more than half (54%) respondents of 4565 individuals reported having been a victim of "road rage", which is the extreme level of aggressive driving, in the past 12 months (DCPC, 2005). A telephone survey undertaken by Wells-Parker et al. (2002) with 1,382 people in the United States showed that 22 percent of the respondents often said bad things to themselves or complained to passengers, and 40 percent indicated that they had honked or yelled through the window in annoyance sometimes (Table 1.1). A study by Mizell (1997) showed that an average of at least 1,500 people are injured or killed each year in the United States as a result of "aggressive driving".

A number of studies indicate that car-related factors, such as communication difficulties (Parkinson, 2001) (Byrne, 2000), anonymity (P. A. Ellison, Govern, Petri, & Figler, 1995) or dehumanisation (Johnson, 1997) between drivers contribute to aggressive driving behaviours. This is because these factors increase the incidence of misunderstanding, reduce the feeling of empathy and weaken the external forces to abide by the social norms (Novaco, 1998).

Table 1.1 Responses of "road rage" telephone survey by Wells-Parker et al. (2002)

Behaviour	**Frequency (percent)**			
	Never	**Rare**	**Sometimes**	**Often**
Say bad things to yourself about another driver	15	23	40	22
Complain/yell about another driver to your passenger	26	22	39	13
Give other drivers dirty looks	42	17	32	8
Honk/yell at someone through window	62	18	17	3

Obscene gestures at other drivers	84	9	6	1
Think about physically hurting other drivers	89	5	4	1
Follow/chase other driver in anger	97	3	<0.05	0
Make sudden or threatening driving moves	95	4	1	<0.01
Tailgate others to force move	87	7	6	<0.1
Speed past other car/ roar engine to show displeasure	87	8	6	<0.05
Keep someone from entering lane from anger	81	12	6	1
Deliberately prevent another driver from passing	91	5	3	<0.05
Try to cut another car off road	98	1	<0.05	<0.01
Get out of car to argue with another driver	98	2	<0.05	<0.01
Deliberately hit another car	99	<0.05	<0.01	0
Get out of the car to hurt another driver	99	<0.05	<0.01	0
Carry weapon if needed for driving incident	96	1	2	1

Furthermore, we would like travel to be a positive experience, beyond just reaching the destination. The socially isolated status of drivers has a negative effect on the psychological status of drivers. Being constrained in front of their steering wheels and “interacting” monotonously with non-human-like machines on the road disconnects drivers from their environment and other people, which leads to boredom (Fuller, 2005) and loneliness (Satici, Uysal, & Deniz, 2016), especially in a long way journey and traffic jams. As a result, people try to escape from the “iron cage” and get reconnected, for example, calling or texting their friends. A government survey in 2011 showed that, despite legislative bans, 59% of Australian drivers used their mobiles, with 31% sending text messages while driving (Petroulias, 2009), which severely distracted from the driving task (Manalavan, Samar, Schneider, Kiesler, & Siewiorek, 2002; McKnight & McKnight, 1993).

The recent advent of the connectivity between vehicles combining the broad penetration of social networks has the potential to address the conflicts on sharing the road and social isolation between drivers. It expands the communication channel to the digital layer, and has the potential to enlarge the bandwidth and decrease the anonymity. Schroeter et al. (2012) explicated the notion "social car" to describe this crossover, which utilised the social media and urban informatics in the automotive domain to enhance the communication between drivers, in order to make the journey more enjoyable and safer. Later, this new trend drew the attention of both academia and industry (Juhlin, 2013; Lexus, 2015; Rakotonirainy, Schroeter, & Soro, 2014). However, most of the explorations are limited to case studies and applications. There is no structural research of this area, systematic user studies nor in-depth analysis of the rationales.

In this research, we investigate what challenges and opportunities the emerging digital layer may offer, and what kind of impacts it would exert on the behaviour and experience while the drivers are travelling on future roads.

1.1 RESEARCH QUESTIONS:

We propose the goal of this study:

> *Designing different social-car applications to enrich the communication between drivers and positively influence driving behaviour and experience.*

In this dissertation, social-car applications refer to the novel applications which enhance communication between drivers facilitated by networking among vehicles. Regards to the driving behaviour and experience, in this research, we aim to mitigate two problems caused by the existing limitations in communication: conflicts on sharing the road and social isolation among drivers.

We further concretised the goal into two research questions:

1) Does digitally augmented communication help to mitigate conflicts in sharing the road?

Investigation of the reason behind conflicts on the road is essential for positive intervention with digital communication. A causal model was used for interpreting the aggressive driving behaviour on the road (DCPC, 2005).

According to the model, communication difficulties is one of the car-related factors of aggressive driving. Limitation of communication may deprive the possibilities to convey dissatisfaction, apology or appreciation between drivers. Limited communication also makes it difficult for road users to obtain full information about others' actions, which may lead to misunderstanding on the road. Enlarging the communication bandwidth between drivers, the concepts *Likes & dislikes* and *CarNote*, were used as probes to evaluate the influence on the driving behaviour and misunderstanding (Figure 1.1).

2) Does digitally augmented communication reduce the social isolation of the drivers?

The vehicle does not only act as a tool taking people from A to B, but may also provide pleasures. Although we share the same road with other drivers, interacting with anonymous people sitting in enclosed machines leads to a socially isolated status. To understand the consequence of the social isolation of drivers, a series of studies of social closeness and belongingness (Baumeister & Leary, 1995) were conducted.

Social closeness may be defined as "the experience of positive emotions towards another individual or set of individuals" (R. R. Ratan & Tsai, 2014). Being isolated in cars decreases the social closeness, and increases the incidence of driving aggression (Gulliver & Begg, 2007; Mitrevska, Castronovo, Mahr, & Müller, 2012; R. R. Ratan & Tsai, 2014; Seidman, 2013). Humans are social in nature, and belongingness is a basic human need. Belongingness requires positive personal contacts as well as perceived interpersonal bonds or relationships. The isolation between drivers compromises belongingness (Baumeister & Leary, 1995), which may result in loneliness (Satici et al., 2016) and harm to the driving experience. The concepts *iSticker* and *MusicHound* were used as probes to influence the social closeness between drivers and belongingness in the journey.

These four concepts were selected, elaborated, prototyped and evaluated to answer the research questions and investigate the research goal.

1.2 METHODOLOGY: INVESTIGATING SOCIAL COMMUNICATION BETWEEN DRIVERS BY APPLICATION PROBE

The social communication between drivers facilitated by vehicle-to-vehicle technology does not exist in current driving scenarios, which makes it difficult to investigate the utility and usability by questionnaires or interviews. Therefore, in this dissertation, we created four novel applications as probes, that convey different types of information, to evaluate the relationship between digitally augmented social interaction and the psychological and behavioural influences on driving through experiments.

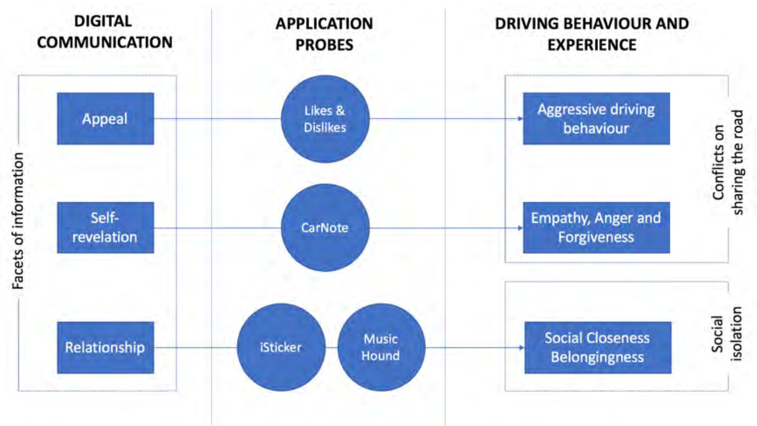

Figure 1.1 Using application probes to evaluate the relationship between digital communication and driving behaviour/experience: Appeal information delivered by "Likes & Dislikes" for aggressive driving behaviour; Self-revelation information by CarNote for Empathy, Anger and Forgiveness; Relationship information by iSticker and MusicHound for Social Closeness and Belongingness.

Thirty novel ideas were generated in a brainstorming session. Next, all the concepts were investigated by the Co-constructing stories methods (Buskermolen & Terken, 2012) among twenty-two participants to evaluate the acceptance. For further analysis of different digital content that may be exchanged between drivers, we applied the *Four-sides communication* *model* (Schulz von Thun, 2008). This model holds that any message contains information on four sides (fact, appeal, self-revelation and relationship), and a message may emphasise any particular side. This model enables us to decompose the message and analyses the influence by the different communication aspects. Then four concepts, which emphasise different communication aspects and address distinct problems (conflicts on the road and social isolation), were selected as probes for further investigation (Figure 1.1).

Figure 1.2 The driving simulator.

All these concepts were further developed into prototypes and evaluations were conducted in an advanced driving simulator (Figure 1.2). As our research questions concern the influence of communication on driving behaviour and experience, compared with a field study, a simulator study has the following advantages: Firstly, it is easier to control variables in the scenarios, such as other vehicles' behaviour, road conditions or the weather etc. Secondly, the content, form and timing of digital messages that are conveyed to the participants can be accurately controlled. Thirdly, rich driving behaviour data can be obtained from the simulator for further analysis, such as path, velocity, behaviour of surrounding traffic, etc. In contrast, a field study requires many cars equipped with vehicle-to-vehicle communication devices; an enclosed scenario containing various roads, viaducts, entrance ramps and exit ramps etc; and a lot of people to drive the vehicles. This is apparently difficult to be arranged.

However, there are also some disadvantages of the simulator study. For example, it is difficult to evaluate the acceptance of the application due to the lack of realism of the simulation. The limitations will be discussed in chapter 8.

1.3 THESIS OUTLINE

Chapter 2 elaborates the limitations of communication between drivers, as well as two related problems: conflict on sharing the road and social isolation. The latest vehicle-to-vehicle communication and everywhere available social networks have the potential to tackle these problems. Then the state of the art of this domain is introduced and a structured framework is proposed to interpret the forthcoming social communication between drivers. The framework suggests that the vehicle is an interface which enables drivers to communicate with each other both through the physical and digital layer. According to this framework, all social-car applications are classified into four categories, and our research focuses on *synchronous-nearby* applications.

Chapter 3 presents the process of utilising the *CoConstructing Stories* method to investigate novel concepts, in order to find out what kind of social applications would be accepted by drivers and which factors influence people's willingness to receive or send social information.

Chapter 4 introduces the *Four-sides communication model* to describe different dimensions of digital messages exchanged between drivers. Combining this model with the work in previous chapters, five criteria were proposed to select concepts for further development. Finally, four applications were developed and elaborated as probes to investigate social communication between drivers.

The communication difficulty between drivers is one of the car-related factors that may lead to aggressive driving behaviour (DCPC, 2005). Chapter 5 introduces the concept *likes and dislikes*, which enlarges the communication channel by exchanging the appeal-side information between drivers. The concept was developed, designed and prototyped in a driving simulator. Three rounds of evaluations, which were for sending, receiving and reviewing afterwards feedback, were conducted. The results showed that the system positively influenced people's driving behaviour and was accepted by most participants.

Participants' feedback of *Likes and dislikes* suggests that only exchanging binary information on appeal-side is not sufficient. Chapter 6 presents the concept *CarNote*, which in-depth enlarges the communication bandwidth by disclosing information of driver's special status to reduce misunderstanding (Figure 1.3). The concept was designed and prototyped in a driving simulator, and user experiments were conducted. Both qualitative and quantitative results support the hypothesis that self-revelation information increases people's empathy, forgiveness and reduces anger for others' driving behaviour.

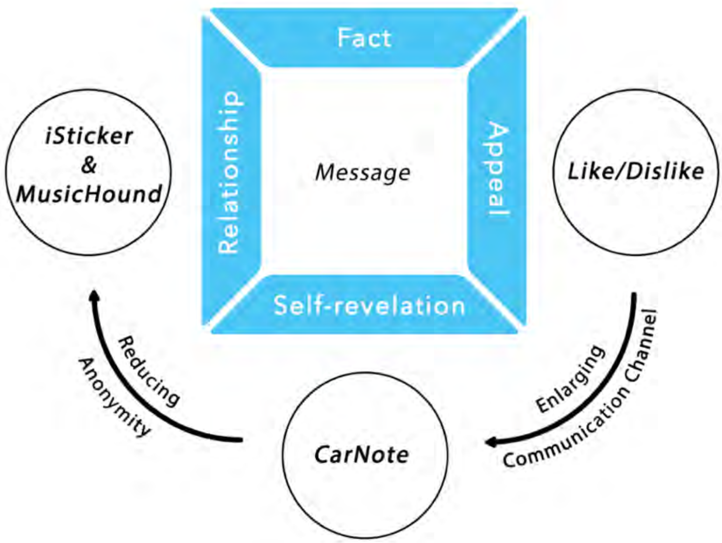

Figure 1.3 The sequence of four studies.

Besides the communication difficulty, anonymity is another car-related factor of aggressive driving behaviour (DCPC, 2005), as social closeness between drivers also exerts influence on the drivers' coordination with each other (Caspi et al., 1997; P. A. Ellison et al., 1995; Gulliver & Begg, 2007; Mitrevska et al., 2012; R. R. Ratan & Tsai, 2014). Chapter 7 introduces the concepts *iSticker* and *MusicHound*, which reduce anonymity by exchanging relationship-side information (Figure 1.3). These two concepts were prototyped in a driving simulator and evaluated by user experiments. Qualitative and quantitative results supported the conclusion that relationship information enhances social closeness on the road.

In chapter 8, the insights related to the research questions in this introduction are summarised, and the limitations of this thesis and future research directions are presented.

2 Motivation and a Unified Framework

In chapter 1 we discussed our research goal and outline. In this chapter, the problems caused by the limitations of communication are elaborated, related research is presented and a systematic analysis of this domain is discussed, for the purpose of finding potential solutions of our research questions.

As drivers need to coordinate with others to share the road, the social nature of driving behaviour should be considered. *Vehicle-to-vehicle(V2V)* (Yang, Liu, Vaidya, & Zhao, 2004) communication has the potential to facilitate the communication between drivers . However, most of the research on *V2V* communication focuses on enabling *cars* to “talk” to each other, and does not concern the communication between drivers inside the vehicle. The everywhere penetrated *locative social network services (LMSNs)* (De Souza Silva & Frith, 2010) and *computer-mediated communication (CMC)* has the potential to connect drivers (Juhlin, 2013; Schroeter et al., 2012). Based on previous research of the *LMSNs* and *CMC*, we propose a structured framework to interpret the forthcoming social network among drivers. Moreover, the possible social applications on the future road are categorised into four groups, and our study focuses on one of them, *synchronous-nearby* communication. We further suggest that integrating the physical layer and the digital layer provides the opportunity to tackle the two main problems caused by the limited communication between drivers: conflict in sharing the road and social isolation.

2.1 LIMITED SOCIAL INTERACTION ON THE ROAD

A driver has frequent encounters with other drivers. In each journey, the driver may "meet" hundreds of others on the road, and they need to coordinate with them for sharing the road infrastructure. However, the contact between drivers is an odd form of social interaction: It has features of face-to-face interaction as drivers are in proximity distance and communicate synchronously with each other. But compared with face-to-face interaction, the communication channels have a rather narrow bandwidth.

Juhlin et al. (2013) propose two factors that constrain the communication between drivers: the speed of the vehicles and the enclosed position of drivers. Firstly, vehicles are usually running at high speed on the road. Therefore, "the durations of the encounters between drivers are often rather short, ranging from a couple of seconds if the cars meet in opposite lanes to minutes if they travel in the same direction."(Juhlin, 2013, p.5) Also, drivers have to pay attention to the road for avoiding crashing into other vehicles moving at high-speed. Few cognitive resources are left for social interaction between the drivers. Secondly, the social communication is influenced by the steel shell and the tinted glasses of vehicles. The communication between the drivers is limited to the signals of cars such as horn, gestures, indicator or using the clunky movement of the vehicles as a form of "car body-language", which depersonalises the drivers and keeps them anonymous.

Renner et al. (2006) compare *face-to-face* with *driver-to-driver* communication (Table 2.1). They argue that *face-to-face* communication is "largely based on verbal communication, but highly supported by non-verbal cues, such as gestures, facial expressions, gaze, etc." In contrast, *driver-to-driver* communication has to rely on the positioning and the signal systems of their vehicles. Furthermore, it is impossible to verify the intent of the involved drivers. The coordination depends on the pre-set rules of the traffic, where drivers have an "established understanding of the regularities and rules of traffic behaviour in various situations".

Table 2.1 Characteristics of driver-to-driver and face-to-face communication (Renner & Johansson, 2006).

	Driver-to-driver	**Face-to-face**
Time available	Very limited.	Usually not critical.
Means for communication	Vehicle positioning, vehicle signalling.	Language, gestures, facial expression, gaze, etc.
Consequence of misunderstanding	It is difficult to recover due to limitations in time and means of communication. Misunderstanding may lead to incidents or crashes.	It can easily be recovered. Humans have a large repertoire of established mechanisms for recovering from communicative misunderstandings.
Settings	Highly scripted, i.e. well established understanding of regularities of behaviour.	The level of scriptment varies depending on the context and situation.

2.2 PROBLEMS CAUSED BY THE LIMITED SOCIAL INTERACTION BETWEEN DRIVERS

This limitation of the social interaction may meet the trend that our society emphasises more and more on autonomy and privacy, in which casual contact with others is threatening or overwhelming (Sutko & Silva, 2011). Friedman (Friedman, 1989) described the car as "an effective filter in dealing with the incredible abundance of the city" and "a private box and public stage." In fact, many drivers enjoy driving because of "being alone" (Redshaw, 2012), which is a pleasant feeling for their sake. As Freund & Martin (1993, p.104) argued:

> *"Though such experiences can be seen as contributing to the erosion of community, serving as substitute pseudo-relationships, and as severing contact with the natural and social environments, they need not be seen as altogether problematic."*

However, being locked in "private space-bubbles" (Fotel & Thomsen, 2002) may negatively affect social interaction in public and harm the civil society. Leckie points out that cars are "semiprivate metal containers" (Leckie & Hopkins, 2002), which "reshape our public streets, sidewalks, neighbourhoods, and daily journeys". The relationships between the drivers are formed by the design of cars. As Lupton (Lupton, 1999) articulates this idea:

> *"When one is driving, one becomes a cyborg, a combination of human and machine. The notions of individual space, social norms and relationships change to suit this combination, to the point that drivers tend to humanize cars or, reversely, to relate to other drivers as machines, thus dehumanizing them."*

In this research, we aim to address two problems which are caused by the limitation of communication between vehicles: conflict in sharing the road and social isolation while driving.

2.2.1 Conflicts in sharing the road

The primary purpose of interaction between drivers is to negotiate on how to share a common section of a road. However, such negotiation is not always successful. Current signal systems, limited by the bandwidth of the communication channel, with little humanity and courtesy, seem insufficient for expressing the driver's intention and providing a social context. Such situation may lead to ***misunderstanding*** on the road. "Every silly act of driving could be interpreted by an angry driver as aggressive and insulting and thus provoke an aggressive response" (VICTORIA, P.O. 2005). For example, when overtaken by a fast driver, instead of thinking of the driver as being a mother taking her sick child to the hospital, she may simply be thought as an aggressive driver. Moreover, it is very difficult to apologise for unintentional mistakes. It is suggested that if a driver can send an apology for his unintentional mistake, 65 percent of "road rages" would not happen (Pavelka, 1998).

Furthermore, the depersonalised and anonymous nature of vehicles may contribute to ***irresponsibility*** on the road. The distance between drivers and the design of the vehicles (metal frames, tinted windows) incur a feeling of anonymity (DCPC, 2005), which decreases the social awareness. "An individual becomes anonymous when he or she cannot be identified by others and, therefore, cannot be evaluated, criticised, judged, or punished" (Zimbardo, 1969). Therefore, the common social norm regularising people's behaviour does not work well as usual, which leads to unaccountable usage of the road. Drivers can usually escape from the scene of violence, which has been widely demonstrated as one of the main factors influencing the decision to act violently on the road (P. A. Ellison et al., 1995; Shinar, 1998). Wiesenthal et al (1992) found that the frequency of traffic rule violations was greater for those vehicles with tinted windows.

2.2.2 Social isolation

The vehicle should not only act as a tool taking people to the destination, but also be an enjoyable space to stay in during the journey. However, from the social perspective, the car is an isolated space. While driving, people are encapsulated in a "domestic, cocooned, moving capsule, an iron bubble" (Urry, 2007). This situation negative influences the psychological status of drivers.

Humans are social by nature. The need of ***belongingness*** is "one of the three basic motivating principles which underlie social behaviour" (Baumeister & Leary, 1995; Rettie, 2003). Being constrained in front of their steering wheels and "interacting" monotonously with non-human-like machines on the road detaches drivers from their environment and social society. As a result, it decreases the feeling of belongingness, which may result in loneliness (Satici et al., 2016) and be harmful to well-being. Nowadays, this problem becomes more obvious, as social networks such as Facebook and mobile internet services make us stay in touch anywhere, anytime, including when we are driving on the road. But they allow us to stay connected to people at a distance, instead of enabling communication with people nearby. According to an interview by Redshaw et al. (Redshaw, 2012), some drivers who commute on the same route every day complain about the boredom of spending time on such journey and describe it as a compulsory task, especially when traffic is dense and they "need to be somewhere at a particular time". Therefore, while our bodies are physically constrained in the vehicle, our minds are trying to escape from the “iron cages” and regain the connection with the outside world. Nowadays, this phenomenon becomes more obvious while we are getting used to stay always online using our mobile devices.

As result, using mobile devices in vehicles becomes a significant factor of driving distraction. People look for their own solutions and that causes safety issues. They engage themselves in dangerous activities such as making phone calls and texting their friends even though they know these activities may lead to severe distraction from driving. A government survey in 2011 showed that, despite legislative bans, 59% of Australian drivers used their mobile, and 31% sent text messages while driving (Petroulias, 2009).

In conclusion, although driving a car meets our need for autonomy, disconnection with others leads to a series of problems, decreasing the pleasure of driving, and causing safety issues on the road. New technology is required to address problems.

2.3 COMMUNICATION TECHNOLOGIES

Recently, developed *Vehicle to Vehicle (V2V)* communication technology, which enables information transfer between vehicles, offers opportunities to enlarge the channel of information exchange. However, current V2V communication research mainly focuses on transferring data between vehicles, and not on enhancing driver-to-driver interaction. On the other hand, the *locative mobile social networks (LMSNs)* become an interface to locate people and connect people anywhere at any time. The combination between *V2V* technology and *LMSNs* have the potential to address the problems mentioned in the previous section.

2.3.1 Vehicle-to-vehicle (V2V) communication

Vehicle-to-vehicle (V2V) communication is a technology that allows "talking" between nearby vehicles (Yang et al., 2004). *V2V* communication relies on equipment in vehicles that uses dedicated short-range radio communication (DSRC) to exchange information. *V2V* has a decentralised structure: when two or more vehicles are in radio communication range (normally several hundred metres), they establish an ad hoc network where all vehicles in this network know each other’s position, heading, speed and braking status.

V2V communication may dramatically decrease the number of deaths and serious injuries caused by accidents on our roads. An NHTSA study of connected vehicle technology has shown that *V2V* communication has the potential to reduce up to 80 percent of crashes, which would save 1083 lives every year (NHTSA, 2014). *V2V* communication has significant advantages over the sensors that are implemented in nowadays high-end vehicles, such as radar and cameras. It can provide much earlier warning and is hardly influenced by the circumstance factor, such as weather and obstacles.

In 2012 a pre-deployment project of vehicle-to-vehicle technology was performed in Ann Arbor, Michigan, which involved 2800 vehicles equipped with *V2V* communication by different manufacturers (Eric Paul Dennis & Spulber., 2016). In August 2014 NHTSA reported that vehicle-to-vehicle communication was proven to be ready for deployment (Harding et al., 2014). On December 2016, the United States Department of Transportation (DOT) announced that it is proposing a rule to require car manufacturers in the US market to equip new cars with vehicle-to-vehicle communication technology (NHTSA, 2016). The DOT expects that if a final rule will be issued in 2019, then all vehicles subject to that rule would be required to comply in 2023.

It is predicted that more and more vehicles will be able to communicate with each other in the future (Riener & Ferscha, 2013). However, the *V2V* technology has been conceived as a tool for better traffic planning. After analysis of hundreds of use cases that have been researched based on *V2V* and *V2I (vehicle to infrastructure)* communication, Papadimitratos et al. (2009) provide a representative list of 16 kinds of applications which are categorised into three directions:

1. Transportation safety: Emergency Electronic Brake Lights, Slow Vehicle Warning, Intersection Collision Warning, Hazardous Location Warning, Traffic Signal Violation Warning, Pre-Crash Sensing, Lane Change Warning, Cooperative Forward Collision Warning.

2. Transportation efficiency: Intersection Management, Limited Access and Detour Warning, Cooperative Adaptive Cruise Control and Electronic Toll Collect.
3. User services delivered to the vehicle: Remote Diagnosis/ JIT Repair Warning, Media Download, Map Download/Update and Ecological Drive Assistance

These applications enhance safety and efficiency, which are the most important aspects of traffic. However, they take the experience of driving, which is related to social properties, rarely into account. As mentioned earlier, the road environment should be seen as a social situation and the communication of social aspects should be not ignored. Currently, *V2V* technologies enable "talking" between vehicles, but they do not enlarge the bandwidth of the communication channel between drivers. As a result, the problems of conflicts in sharing the road and social isolation are difficult to be solved only by exchanging sensor data. For example, by transferring speed, position and brake data of nearby vehicles, the "Cooperative Forward Collision Warning" can provide warning information to the drivers if the front car suddenly brakes (Yang et al., 2004). However, it may not mitigate the anger of the following driver who is scared by this event, as there is no communication channel for the front driver to apologise for the behaviour, nor accountability mechanisms such as punishment. Furthermore, the current application of *V2V* does not concern the social communication of non-driving information, such as self-presented identity information, which could help to reduce social isolation in the vehicles.

2.3.2 Locative mobile social networks (LMSNs)

Nowadays, the appearance of mobile phones and positioning services (such as GPS) enables people to connect with and locate each other anywhere at any time. The *locative mobile social networks (LMSNs)* is a promising technology that could be used to enhance social communication between drivers.

Social network services (SNS) have been widely integrated into our daily practices. SNS could be defined as web-based services that allow individuals to (N. B. Ellison, 2007, p.211):

1) construct a public or semi-public profile within a bounded system,

2) articulate a list of other users with whom they share a connection, and

3) view and traverse their list of connections and those made by others within the system.

Later, the popularisation of mobile phones enabled people to get access to *SNS* anywhere at any time, which brought the boom of *(mobile social networks) MSNs*. Moreover, after 2001, the more accurate GPS signals "generated a renewed interest in the development of location-aware social applications". De Souza et al. (2010) proposed the term *locative mobile social networks (LMSNs)* to represent the location-aware technology that enables users to "see each other's position on a map and to interact with one another according to their relative distance in physical space". They differentiate *LMSNs*, traditional *SNS* and *MSNs (mobile social networks)* by comparing the fundamental properties of these networks, such as space, quality, connectivity, nodes and paths (Castells, 2001).

The traditional PC-based social networks "annihilated space and time and emphasised connectivity and nodes, not paths" (De Souza Silva & Frith, 2010). Messages are transferred efficiently and arrive at the next node instantly, and space does not matter. In the non-location-aware *mobile social networks (MSNs)*, although the nodes (users with mobile devices) accessing the internet are moving, their physical locations and the paths of travelling are still irrelevant to the network. In contrast, the *LMSNs* "emphasise the paths, the trajectory space in-between the nodes". For example, the users of the *LMSNs* can see where other individuals are on a digital map and contact the ones nearby. These features are not present in other social networks, such as online chat rooms. Enabled by the everywhere available connectivity in cities and suburbs, and on highways, *LMSNs* connect people, locate people and enable them to communicate in a *hybrid space*, "where the usage of mobile technologies as connection interfaces blurs the traditional borders between physical and digital spaces" (De Souza, 2006).

Applications of *LMSNs*, which blend the digital space and the physical world, have drawn great attention. The “global phenomenon” in 2016, *Pokémon GO*, is a locational mobile game which integrates social elements and augmented reality technology. After being released, it quickly became one of the most popular and profitable mobile apps in that year, being downloaded more than 650 million times worldwide (Sarkar, 2016). Unlike traditional online video games in which players only contact each other in the virtual world, in *Pokémon GO*, players need to cooperate in the real urban space to complete the tasks. For example, the virtual “gyms” are “located” in real buildings in the city. If players want to visit a “gym” as a team, they need to be present in the proximity of the physical building. The cell phone become an interface connecting people in both the digital world and the physical world.

Combining *LMSNs* with *V2V* allows drivers to locate and connect to each other, which may provide the opportunities to solve the problem caused by the limited social interaction between road users. Example of such efforts from literature are presented next.

2.4 RELATED WORK: APPLICATIONS OF DRIVER-TO-DRIVER COMMUNICATION

Although most studies focus on the communication of vehicle-to-vehicle, rather than on the “driver-to-driver”, the trend of combining *computer-mediated communication (CMC), social networks* with *vehicle-to-vehicle* communication has drawn attention of the academia.

2.4.1 Juhlin’s research: case studies

Juhlin et al. (Juhlin, 2013) suggest that as people spend a lot of time on the road, “where a large number of everyday encounters between people occur”, the car should not just be a tool that takes people to their destination. The forthcoming mobile technologies can make the time on the road more “interesting and meaningful” by enhancing the communication between drivers.

In their research, nine innovative applications were provided as probes to explore this domain. The applications ranged from safety related cases, such as sharing the state of the road, through more entertainment-related cases, such as digital games that interact with the landscape passing by outside the car windows, to cases providing means for drivers and other road users to present themselves and show their identities, such as exchanging profile between motorcyclists on the road. All these applications were developed into fully functional prototypes and investigated in the field by ethnographic observation. They saw the prototyped applications as partly inspirational patterns (Löwgren 2005) that might inspire a discussion on how people want to spend their time on the road in the future. Their research attempted to combine a sociological approach with both "transportation research and such domains of computer science as focus on social interaction and user experiences, to provide some form of socio-technical amalgamation". However, at that time, mobile social network devices and services were not popularised, and advanced human computer interaction technologies, such as augmented reality or gestural interaction were not widely implemented. More importantly, there was no structural framework to interpret the properties of their concepts and to categorise them.

2.4.2 Schroeter's research: "social car"

Schroeter et al. (2012) defined the notion of "social car" to describe the "new interactive vehicular applications derived from Social Media and urban informatics". They argued that the two primary goals of the automotive user interface were to make the journey of driving more *enjoyable* and *safer*. However, these two tasks seem to contradict each other, as safe driving is often a boring activity and joy needs stimulation. Previously, the automotive user interface researchers mainly focused on *how* "a driver can safely interact (input/output) with various types of data or information", and a series of novel interaction techniques were proposed, such as head-up display, haptic feedback and speech recognition, but little attention was on *what* kind of new content could be displayed to the drivers. As "place- and time-specific digital information" is increasingly filling the urban landscape, Schroeter et al. revisited the question about *what* kind of "urban informatics data/information or applications may unlock new opportunities of bringing the concepts of *joy* and *safety* together".

They recruited fourteen urban research experts for brainstorm sessions and focus group discussion of social applications which may appear in the future. They categorised all the generated concepts along two dimensions: the intimacy of the relationship and the proximity in space. The participants of this study found the applications which allow drivers and passengers to interact with strangers nearby most innovative and to have “untapped potential” (Schroeter et al., 2012). For example, they suggested a *Rockstar on Wheels* application enabling passengers to have a sing-along competition with drivers in the cars nearby, a public display of one’s average speed, and a digital broadcast application of the currently played music of drivers.

2.4.3 Riener’s research: collective intelligence

Riener et al. (2013) consider social ICT (information and communication technology) on the road in a bigger scope: collective intelligence. According to the socio-ecological model (SEM) of Bronfenbrenner (1977), “social interaction happens in different levels, ranging from the relationship (friends, family) to the community (people with same desires, goals) and finally society (rules, regulations)”. Through social engagement, a local and individual activity may have influence on a global scale.

Inspired by biology, they refer to “*Stigmergy*”, which is a coordination concept derived from the collaboration of social insects. A fundamental characteristic of “*Stigmergy*” is that communication takes place using environment modifications, which affect subsequent behaviour. For example, an ant changes the environment by leaving a trace which can be sensed by other entities, and these “markers” may lead them to the food source. This paradigm can be applied to vehicles moving on a motorway with ICT. A car may “drop” information, such as limited sight due to fog or slippery road while passing a section, and other cars coming close to the spot can receive proactive warning information. They list the goals of socially aware vehicles, which are: Driving safety, sustainability, driving experience and pleasure, social forgivingness, enhanced self-assessment and better prediction. They also point out the “pitfalls” against the utilisation of social cars (e.g. privacy and security).

Moreover, an online survey was conducted to compare the drivers’ current in-vehicle technology use and to investigate the needs for implementing new vehicle-network services in three countries: Austria, USA and Korea in May 2012, with 225 participants.

The result showed that about 20% people used “Social Network services (SNS)” in their cars across different cultures (Austria: 5 %, US: 26 %, South Korea: 17 %). Participants were also asked to rate their general thoughts about *vehicle-to-vehicle* communications using five-point Likert-type scales. The results showed that participants were positive to this technology (Austria: 3.7, US: 3.3, South Korea: 4). Furthermore, one part of the survey investigated sixteen new in-vehicle service concepts by Likert-type scale. The top rated concepts were “Intelligent Traffic Guide” (In-car system uses the GPS and telemetry to provide periodic information about the road and traffic signs and warns the driver of any possible violations or danger), “Sensory Bubble” (Car sensors sense and alert external conditions such as temperature, ice, or wet roads; and proximity of objects or other cars) and “Free Parking Slot/ Parked Car Finder” (Drivers can get a map from the server for the location of vacant slots and navigate to the location). The results demonstrated that “drivers in all three countries are still more interested in technologies that will keep them safer, instead of ‘Facebook’ updates’”.

2.4.4 Other related research

There is also some other research on the social communication between drivers. Ratan et al. (2014) suggest three kinds of communication and corresponding purposes on the road:

> *(1) communication between the driver and other people on the road to coordinate movement, (2) communication between the driver and the car to control the car’s behaviour, and (3) communication between the driver and others in general to convey identity.*

They state that communication between drivers to coordinate the movement of the vehicle may be facilitated by internet devices, in addition to the current vehicle signal system. Moreover, they especially emphasise the drivers’ demand to communicate their identities, “socioeconomic status”, “political and cultural attitudes” through the car, which may be enhanced by social media on the road. A survey and interviews with 90 participants were conducted to investigate the relationship between the three types of communication, social closeness and aggressive driving. The results showed that if the communication channel between drivers was enlarged, the social closeness was enhanced, thus the aggression on the road would be reduced. Several “social-mobility services” were proposed, enabling drivers to send “smiley faces and ‘thank you’ messages”, and friendly text such as “It’s nice to share the road with you”, and to share “text-based profile information” and “customized virtual car (an ‘avatar’)”.

Lamas et al. (Lamas, Burnett, Cobb, & Harvey, 2014) investigated six driving scenarios with 24 participants in order to find out the problems caused by communication limitations between drivers. They suggested that the usage of innovative communication devices may address this problem. Several recommendations on the communication devices were generated, such as avoiding anonymity of the sender, set pre-defined text messages, avoiding distraction or showing driver status.

According to a survey of 92 participants by Kim et al.(Kim, Kim, & Lee, 2016), four emotions that the drivers want to express mostly were: appreciation (24 instances), anger (17 instances), regret/apology (16 instances), and surprise (9 instances). A prototype which could display the *emoji* of these four emotions on the back windshield to deliver drivers’ emotion status was implemented in a vehicle, for the purpose of investigating driver’s feedback of knowing the others’ emotion and communicating emotion themselves. The results showed that rich communication between drivers might eliminate their negative emotions.

To sum up, the social communication between drivers has drawn attention by some researchers. However, there is no systematic overview of the communication between drivers. In the next section, we will introduce a framework of digital augmentation, to gain such an overview.

2.5 VEHICLE AS AN INTERFACE FOR COMMUNICATION IN DIGITAL AND PHYSICAL LAYERS

Current studies of the communication between drivers facilitated by connectivity between vehicles mainly focus on application exploration, or technology forecasting, and lack systematic analysis. To provide a structured view over the social communication augmented by the Internet, we suggest driver-to-driver social interaction may be seen as an extension of *locative mobile social networks (LMSNs)*. We take the social network services as a reference to provide insight into driver-to-driver communication in the future. A framework is proposed where vehicles are described as the interface to access the “Hybrid” urban social space (De Souza, 2006). Based on this framework, a categorization of the social car applications that may appear in the future social cars is also provided.

2.5.1 Vehicles as social interfaces: a framework

The connectivity of vehicles and locative information transform the road environments into *hybrid social spaces* (De Souza, 2006), as it allows drivers and passengers to contact the others not only in the physical world but also in the digital world. The connected vehicle acts as the interface of this transformation: On one hand, it provides mobility for the driver to travel in the physical world; on the other hand, it becomes a node in the network. The relationship between the drivers on the road can be interpreted using a *social graph*, such as the *multigraph* (Gjoka, Butts, Kurant, & Markopoulou, 2011), which presents multiple channels of social connection between actors – in our case, drivers. There are two levels of relationship in the driving situation: the *physical layer* and the *digital layer* (Figure 2.1).

In the *physical layer*, the *arcs* connecting people represent the physical contact in the same geographical locations. We name these geographical locations where the contact happens as *zones*. In the *zones* there is physical contact, which includes various social interactions such as eye contact on how to share the road or facial expressions when being stuck in the traffic jam. The contact between drivers is limited to real-time social communication within the visual or auditory range. However, in contrast with the freedom of moving to a different location in the digital world by just “one click away”, the contacts in the *physical layer* emphasise the geographical properties such as road condition, traffic density or weather.

In the *digital layer*, the *arcs* that connect people represent the digital contact on the Internet. The contact happens in various social applications, which we name *systems*. In the *systems*, people are connected to each other without being limited by space and time. A driver may not be only in contact with others who are a hundred miles away but also acquire the "trace" information which other drivers left behind several hours ago. Furthermore, there is no limitation of the number of people the driver interacts with. However, the connection in this layer is easy to be cut off, as people can decide whether they are present in the systems or which systems to get into.

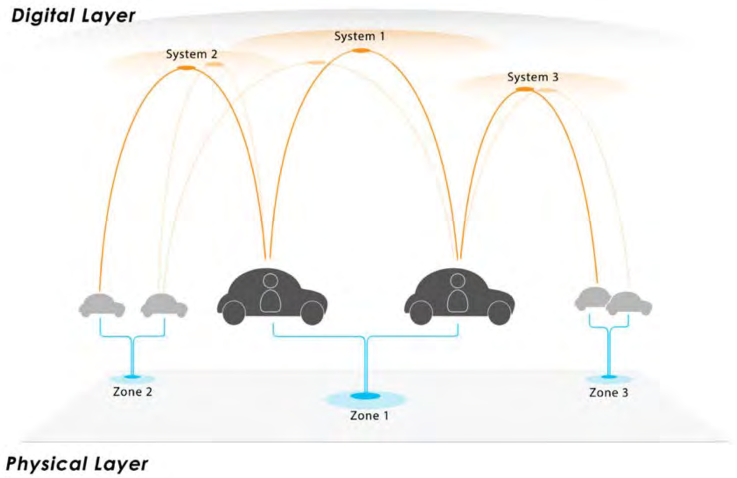

Figure 2.1 Two layers of communication between drivers enhanced by connected vehicles

This framework helps to understand the combination of the information exchange in social networks and the physical contact of vehicles, containing two kinds of "spaces", the *physical space* and the *digital space*. In the next section, *time*, will be introduced as another dimension to classify different types of social applications.

2.5.2 Classification of social applications on the road and related cases.

Kaplan et al. (Kaplan, 2012) give an introduction to the general topics of mobile marketing and mobile social media. They distinguish four types of mobile social media applications, depending on "whether the message takes account of the specific location of the user (*location-sensitivity*) and whether it is received and processed by the user instantaneously or with a time delay (*time-sensitivity*)". In a study of possibilities of collaborative design facilitated by technical support, Saad et al. (1995) propose a matrix of commonly available communication means for design teams, also structured by a similar time and place relationship.

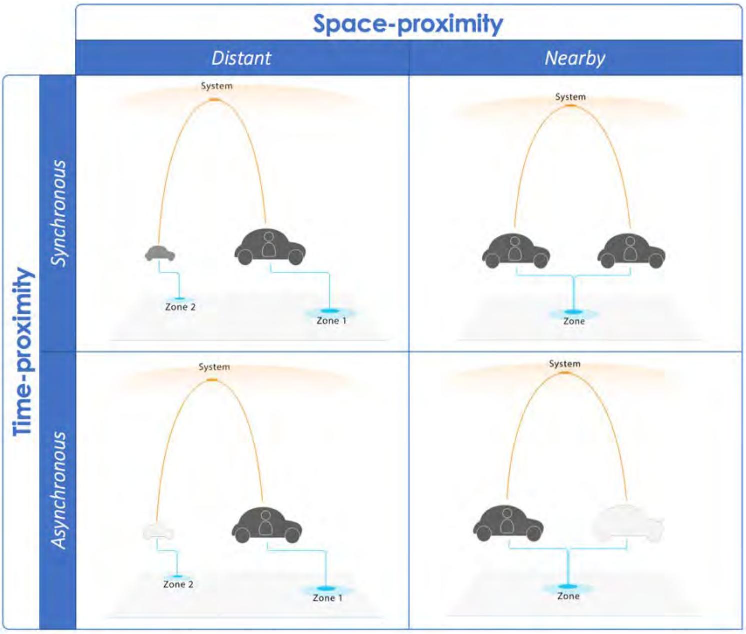

Figure 2.2 Classification of social application on the road

Inspired by these researches, the social communication between drivers enhanced by digital augmentation may also be categorised by two dimensions: *time-proximity* and *space-proximity* (Figure 2.2).

With respect to the time-proximity dimension, we distinguish forms of social interaction in terms of the synchronisation of communication. In synchronous communication, people are “participating at the same time and wait for replies from each other” (Shore, 2016) (e.g. real-time video chat). Asynchronous communication “occurs in delayed time and does not require the simultaneous participation of people” (Shore, 2016) (e.g. email). With respect to the space-proximity dimension, forms of social interaction may be distinguished in terms of geographical distance. High space-proximity means social contact with people nearby, whereas low space-proximity refers to social contact with people at a distance and assisted by the Internet. Next, we show some samples of applications in different categories.

Synchronous-distant cases

For the *synchronous-distant* category, a typical application is the widely used real-time traffic information. For example, *Waze* [1] users may be informed about an accident which is reported by other drivers in miles away, to re-plan their routes (Figure 2.3).

Figure 2.3 Waze app for iOS, source: CBR, image by Joe Clark (2017).

Knobel et al. (2013) present an in-car system *Clique trip* (Figure 2.4), which is designed to create a relatedness experience. Clique trip displays the positions of friends when they are travelling in different cars to the same destination. It also opens a communication channel allowing them to talk to each other.

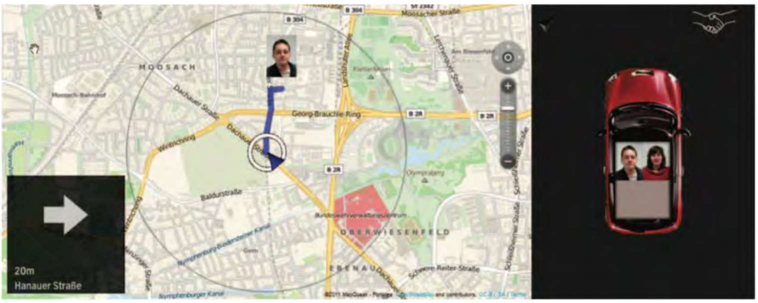

Figure 2.4 Clique Trip (Knobel et al., 2013)

[1] www.waze.com

Asynchronous-distant cases

Besides real-time traffic information, nowadays, navigation software such as *TomTom*[1] provides traffic prediction. The predicted traffic condition is based on analysis of a large number of users' previous data, instead of direct social communication. Therefore, this example may be categorised as *asynchronous-distant* communication (Figure 2.5).

Figure 2.5 Traffic prediction feature of TomTom[2].

Asynchronous-nearby cases

Riener et al. (2013) suggest the concept of "braking/accelerating recommender system", which shares with non-locals the "expert knowledge" (e.g., when and how strong to apply the brake) of drivers who are familiar with a place (Figure 2.6). Based on this concept, they propose a "Social driving app" that allows experienced drivers to collect and share driving data (speed, gear, brake force, etc.) and introduces a ranking system to motivate the individual driver to follow the instruction from the system while driving (Riener & Reder, 2014) (Figure 2.7).

Synchronous-Nearby applications

The applications in the last category, *synchronous-nearby* communication, enable drivers to directly interact with nearby drivers, and combine digital information with drivers' sense of the physical environment where they are located. Drivers' visual, auditory and haptic sense "stays" in the

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[1] www.tomtom.com

[2] Pictures from: https://www.tomtom.com/en_gb/sat-nav/tomtom-traffic/

physical world, but the augmented and extended digital layer, may help them acquire better perception and understanding of the surrounding. Kaplan et al. (2012) state that "*space-timers*" applications are the most sophisticated form of mobile social marketing applications. Schroeter et al. (2012) suggest that there is an untapped potential in the communication between drivers and passengers in nearby cars.

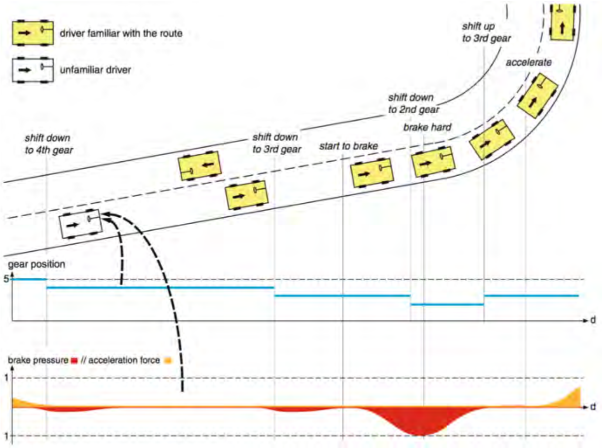

Figure 2.6 Driving advice from familiar drivers help non-locals to optimise driving behaviour (braking/accelerating) and thus to feel increased pleasure of driving and to optimise carbon dioxide emission (or fuel consumption) (Riener & Ferscha, 2013)

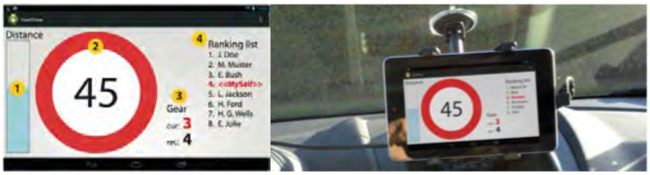

Figure 2.7 User interface of the "Social driving app": sharing expert knowledge by showing dangerous bend, "Children warning", gear recommendation as well as a ranking list for economic driving performance. (Riener & Reder, 2014)

In this dissertation, we mainly focus on the social interaction in this category as it has great potential to alleviate the conflict of sharing the road and social isolation.

2.6 SYNCHRONOUS-NEARBY APPLICATIONS: UNTAPPED POTENTIAL IN THE COMMUNICATION BETWEEN DRIVERS

Synchronous-nearby applications require more accurate positioning services and wide connectivity of vehicles. As a result, the implementation of these applications is difficult to be realised in real cars in real traffic at the current stage. However, it may be foreseen that the development of high accuracy location services, human-machine interaction technologies and V2V communication will extremely facilitate the implementation of *synchronous-nearby* social applications in the near future.

Examples of synchronous-nearby applications from both academia and industry are introduced below. The particular characteristics of the communication in these examples are analysed based on the framework proposed in section 2.5.1. We argue that there is a design space for social applications aiming at enhancing the synchronous social communication between drivers in the proximity.

2.6.1 Cases of synchronous-nearby applications

Rakotonirainy et al. (2008) propose an in-vehicle avatar system to communicate drivers' intention and increase social awareness via eye gaze. Participants were asked to drive through different types of intersection in the driving simulator. Virtual avatars representing the head and eye gaze of other drivers were displayed on the top of their cars. The result showed significant difference in terms of eye gaze pattern when an avatar was displayed, which indicated that the presence of the avatar influences on drivers' behaviour. The result also show some indications that drivers refer to the avatar when needing information on the intention of others.

Motorcycling is a highly mobile activity, and motorcyclists are also explicit about their interest in other motorcyclists, which is visible in the way they often greet other bikers they meet along the road. Esbjörnsson et al. implemented a prototype called "*Hocman*" which "enhances brief traffic encounters between bikers by playing a sound clip and automatically exchanging personal HTML pages" (Esbjörnsson, Juhlin, & Östergen, 2003). Field study results showed that bikers enjoyed such added value to biking.

As mentioned earlier, Schroeter et al. (Schroeter et al., 2012) summarised future possible social applications which were generated by brainstorm sessions, and they discussed the details of three examples in this category.

1. *Rewarding Achievements:* With this application, drivers are able to rate other drivers' behaviour. Based on the data of crowd-sourced ratings, some drivers could get badges for "friendly" or "consistent driving", "courteous way-giving", "good parking", etc., which would be shown to other drivers. This application may contribute to cultivate friendly driving behaviour (Figure 2.8).

Figure 2.8 Rewarding Achievements (Schroeter et al., 2012)

2. *Allowing Social Expression:* Drivers could show personalised and digital "boot stickers", which express the information such as "in a hurry", "relaxing family road trip", "driving kids to school" or "exploring the city", etc. This application could provide more social cues to the surrounding drivers (Figure 2.9).

Figure 2.9 Allowing Social Expression (Schroeter et al., 2012)

3. *Visualising Degrees of Separation:* This application could analyse each driver's social networks to calculate the degrees of separation from each other, e.g., people could know the front driver is his friends' friend. This application may decrease anonymity by establishing social bonding between drivers, for the purpose of mitigating aggressive, anti-social and selfish driving behaviour (Figure 2.10).

Figure 2.10 Visualising Degrees of Separation (Schroeter et al., 2012)

Currently, the lack of accuracy of positioning services and the low penetration of connectivity between vehicles limit the implementation of the *synchronous-nearby* applications. As a result, most explorations are either concepts or research prototypes. However, there are some attempts in the market. A start-up company, *Nexar*[1], provides real-time collision warning by existing technology: cellular networks and smartphones (Figure 2.11). Their dash camera APP can detect a driver's hard brake by the sensor of a smartphone, and warning information is sent to nearby drivers to prevent a collision. However, limited by the accuracy of GPS, it cannot inform nearby drivers which car is hard braking. Another interesting feature of *Nexar* is that it can record the front cars' impolite driving behaviour, such as cutting off and hard brake, through smartphones' camera and their license plate numbers to build a driving score for each vehicle. Then this APP will alert the users if they are close to a "bad driver".

[1] https://www.getnexar.com

Figure 2.11 The Nexar application[1]. Images source: Nexar (2016).

2.6.2 Complementation of the physical layer and digital layer communication

We argue that the Synchronous-Nearby applications may be seen as a 1) special form of *face-to-face social interaction*, 2) which is facilitated by *computer-mediated communication (CMC)*.

In traditional sociology, the *face-to-face interaction* is defined as "the reciprocal influence of individuals upon one another's actions when in one another's immediate physical presence" (Goffman, 1978). As the *driver-to-driver* contact happens within short range, where people can hear, see and influence each other's behaviour, the communication in the physical layer can be seen as a kind of *face-to-face interaction.* However, comparing with normal *face-to-face interaction*, *driver-to-driver* interaction is very special, as the communication bandwidth and duration are highly limited (see section 2.1).

Computer-mediated-communication (CMC) is defined as human communication that occurs via computer-mediated formats, such as email, Instant Messenger (IM) or social networks services (McQuail, 2010). The

[1] https://www.getnexar.com

digital-layer communication between drivers can be seen as a form of *CMC*.

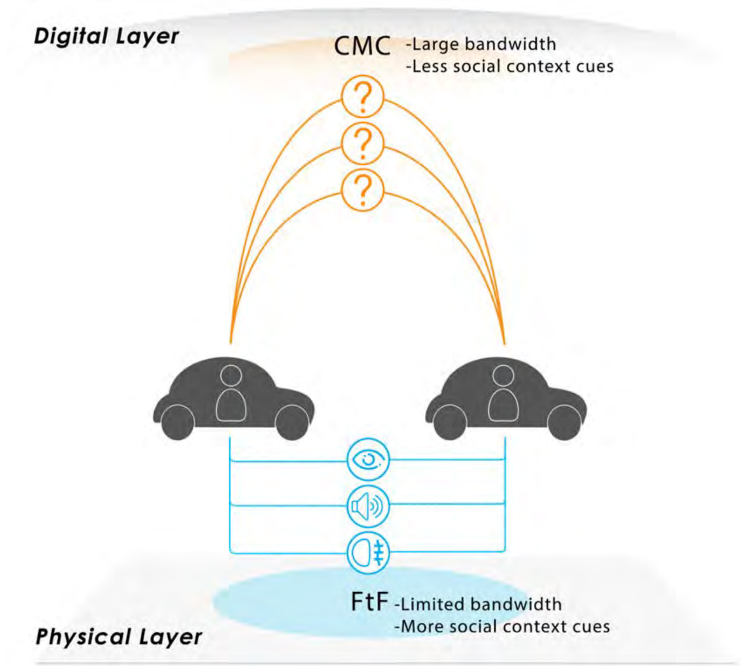

Figure 2.12 Combining communication in two layers.

FtF communication and *CMC* have their respective characteristics, which are complementary in *synchronous-nearby* applications, enhancing the quality of social interaction between drivers (Figure 2.12). Facilitated by *CMC*, the bandwidth of information transfer between drivers is extremely enlarged. For example, beside the signals of vehicles, drivers can also send text, voice or even emoji through the digital layer, which contain rich social information and emotions. From the *"face-to-face" interaction* perspective, drivers are physically present and interact with each other in the same space, and control the vehicle in the same road and traffic. These provide more social context cues which are absent in *CMC* (Kiesler & Sproull, 1986).

2.6.3 *Reducing conflicts and social isolation between drivers by two-layer communication*

The combination of two layers of communication on the road has the potential to deal with the two problem of conflicts and social isolation that originate from the disconnection between drivers.

Firstly, drivers are more "visible" on the road, which may reduce misunderstanding and irresponsible driver behaviour. The combination of *FtF* communication and *CMC* enlarges the bandwidth of communication between drivers, composing a *socially translucent system* (Erickson & Kellogg, 2000). In such a system, socially significant cues are more *visible,* providing social cues of the communication context, clarifying the intention of drivers. Furthermore, the enhanced communication raises the *awareness* of the existence of the others, bringing social rules into play to govern the actions. As drivers know that they are more visible to other drivers, they tend to be more *accountable* for their driving behaviour.

Secondly, drivers can communicate identity information through the car to nearby others, which may increase the social closeness between them and enhance the feeling of belongingness during the journey. Compared with face-to-face interaction, people tend to disclose more personal information by *CMC* (Joinson, 1999), which may decrease the anonymity on the road. For example, drivers can put "virtual stickers" on their cars, and if other drivers have a similar sticker, such as stickers of the same soccer team, cartoon figure or movie characters, they can see each other's sticker when they encounter; Or they may share the music they are playing to nearby others who have the same music taste. All these would increase the closeness and belongingness between drivers, and the pleasure of the journey.

2.6.4 *Design space of social applications on the road*

The above research suggests that the integration of social network services into the communication between drivers may improve their driving behaviour and experience. However, it is unknown what kind of applications that may mitigate the conflicts and isolation on the road. As a result, in the following chapter, we present novel concepts which were generated by brainstorming, and the acceptance of these concepts was investigated with 22 participants.

3 Concept Exploration[1]

In this research, we used novel applications as probes to evaluate the effect of digital information on driving behaviour and experience. Thus, promising concepts should be generated for the experiment. In this chapter, we present an exploration of what sort of social applications would be accepted for a driving scenario and which factors influence people's willingness to receive or send these kinds of social information. We utilised the "CoConstructing Stories" (Buskermolen & Terken, 2012) method to investigate 30 novel scenarios with 22 participants. We found that driver-to-driver communication relating to Safety and Efficiency was well accepted. Regarding the acceptance of driver-to-driver communication concerning the Relatedness between drivers and expressing their Identity, additional information such as the existence of the social bonding is required.

3.1 METHODS: COCONSTRUCTING STORIES

CoConstructing Stories (Buskermolen & Terken, 2012) is a participatory design technique for early, formative concept evaluation to elicit in-depth user feedback and suggestions. The development of the technique is motivated by the link between experiences, memories and dreams, and is

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[1] Based on: Wang, C., Gu, J., Terken, J., & Hu, J. (2014, November). Driver-to-driver communication on the highway: what drivers want. In European Conference on Ambient Intelligence (pp. 315-327). Springer International Publishing.

based on the assumption that “users are better prepared to judge whether novel design concepts will enable valuable experiences in the future if they revive their past experiences first” (Buskermolen & Terken, 2012). The possible social communication in the digital layer on the road requires the development of ITS (Intelligent Transport Systems) technology, auto-pilot technology and novel HMI (Human-Machine Interface) technology. It is difficult to test the social applications by field study. Therefore, we consider CoConstructing stories as an appropriate method with which researchers may evaluate fictional scenarios with participants.

3.2 APPROACH

3.2.1 Group brainstorming and categorization.

Some novel social applications were needed for extensive analysis in the phase of CoConstructing stories. As a result, we conducted brainstorms to generate the social communication concepts. Three rounds of group brainstorming sessions were run with 16 researchers and students in total of different disciplinary backgrounds, such as industrial design and computer science.

Figure 3.1 Ideating while brainstorming.

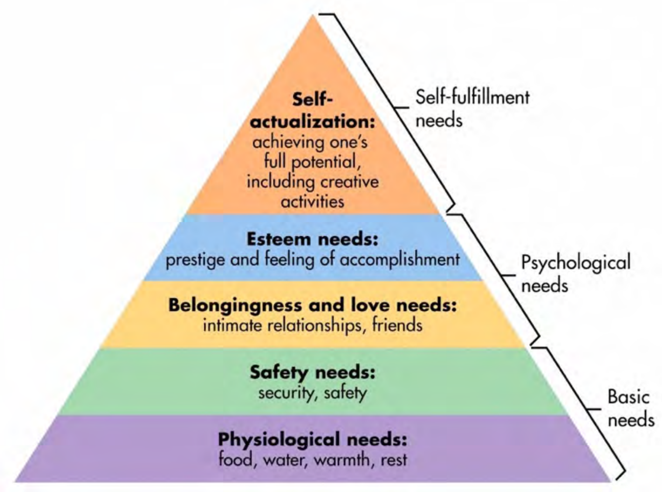

Figure 3.2 Maslow's hierarchy of needs

The brainstorm was conducted in a meeting room with a TV to show questions. Papers and markers were provided for participants to write down the ideas (Figure 3.1). To warm up for brainstorming, the participants were asked about 10 things they like/dislike about driving in 2 mins. Then they were asked one questions that guided the ideation: "What kind of information would you like to exchange with other people on the road?" The participants were required to write down 5-10 ideas on paper cards in 5 mins. Then were asked to pass cards to the person sitting to the left and write additional 5-10 ideas on the cards they received from the person sitting to the right in 5 mins. After that the second question was shown on the TV: "What kind of ideas you would like to know other people on the road?" The participants were required to write down 5-10 ideas on paper cards in 5 mins and exchange cards to write additional 5-10 ideas in another 5 mins. After that, the third question was asked: "What kind of ideas you would like to communicate with other people on the road?" Again, they wrote down 5-10 ideas in 5 mins, exchanged cards and wrote 5-10 additional ideas in another 5 mins.

Table 3.1. Description of all the concepts. S, E, R, I indicate the category each concept belongs to. S: Safety; E: Efficiency; R: Relatedness; I: Identity.

S	*E*	*R*	*I*	*Concepts*
•				C16. Imagine that you can remind the car behind you to keep distance.
•				C17. Imagine that your seat vibrates from left to right to indicate that a car is going to overtake you from your rear of your left.
•				C7. Imagine that your music volume goes down once the car in front of you suddenly breaks.
•	•			C11. Imagine that you can discover a car running near yours cruising its way through automatic cruise control, self-driving etc.
•	•			C8. Imagine your car can express your state: “I’m really in a hurry!”
•	•			C20. Imagine that you can check the driving skill of the driver whose car is in front of yours.
	•			C30. Imagine that you are driving on the highway at night and can discover the nearest cars in front of you.
	•			C26. Imagine that a driver whose child is seized with a serious sickness asks for priority on the emergency lane.
	•			C22. When you are nearing your destination, you can get weather information at the destination from other drivers in real time.
	•			C19. Imagine that you can get Gas discount information if your fuel is low.
	•	•		C4. Imagine that a driver on the road invites you to group with him for “group discount” in a restaurant.
	•	•		C24. Imagine once you are caught in the traffic jam, you can see the road condition in front of you through the front camera of the cars ahead of you.
	•	•		C15. Imagine that if a driver gives you the way to pass, you can “like” his driving behaviour.
	•	•		C23. Imagine that you and your friends will meet in a city, you can discuss the travel plan with your friends while driving.
	•	•		C21. Imagine that you can discover that the driver nearby is working in a similar position or the same industry as yours and that you are separated by two professional connections.
	•	•		C9. Imagine that you can ask the local drivers for help.
		•		C28. Imagine that there is a platform for drivers to post some information on the road, and you can get filtered information that is relevant to you.
		•		C18. Imagine that when you see a trendy car, you can ask for permission of his Facebook.
		•		C12. Imagine that you can discover places that are recommended by other drivers or other drivers often go to.

		•		C6. Imagine that you can send a music track to the front car as a gift.
		•		C25. Imagine you are caught in a traffic jam and have nothing to do. However, you are invited to someone's personal FM. This time it is initiated by a driver with the topic "The match AJAX vs PSV tonight".
		•	•	C29. Imagine that a car smiles to you, because it is the 10^{th} time you pass each other on the highway. Moreover, you can get to know each other
		•	•	C14. Facial expression of car to show the driver's mood: tired, angry
		•	•	C1. Imagine that you can "like" the trendy car on the road.
		•	•	C27. Imagine when you are on the road, the Twitter messages of nearby drivers can be displayed.
		•	•	C10. Imagine that you spot a trendy car on the road, you can check its music genre or restaurants history it often visits.
		•	•	C2. You can get informed if a car nearby is from the same city and heading to the same destination as you.
			•	C13. Through the analysis of each drivers' social graph, your car can show the nearby driver is your friend's friend.
			•	C5. Imagine that some drivers can generate colourful "virtual shields" as decoration by augmented reality technology to show their personalities.
			•	C3. Someone can show the music that he is listening to to other drivers nearby.

After data clustering through all three brainstorming sessions, 30 ideas were generated in total. Then the participants in the brainstorm categorised these ideas into eight themes: safety, comfort, efficiency, lifestyle, skill rating, sharing trips, free offers and communication.

Later the eight categories were combined into four according to the different levels of need (Maslow, 1943) (Figure 3.2 Maslow's hierarchy of needs) by two researchers (design and psychology background). The hierarchy of categories from basic needs to higher needs are Safety, Efficiency, Relatedness and Identity (Figure 3.3). Adjacent categories are overlapping because some concepts belong to both of them.

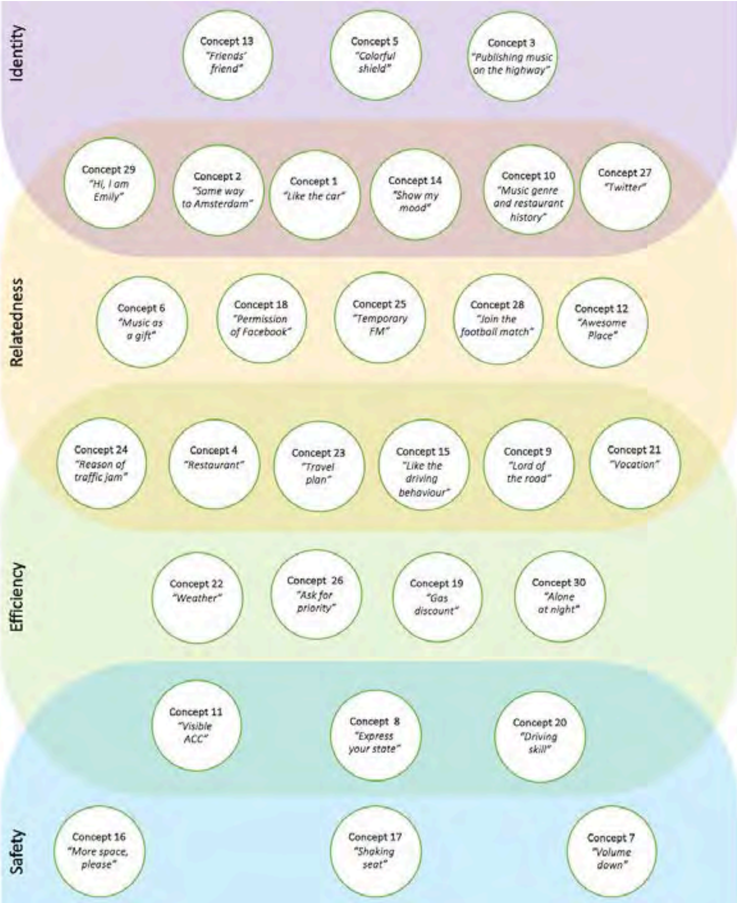

Figure 3.3 The hierarchical categories of concepts

3.2.2 CoConstructing Stories method.

The CoConstructing stories method consists of two phases (Figure 3.4): sensitization and envisioning. The sensitization phase aims to make participants think about their past experiences, “so that in the elaboration phase they can better envision the future” (Buskermolen & Terken, 2012). In this case, in the sensitization phase pictures of relevant scenarios based on real driving experiences (Figure 3.5, Context Layer) were shown to the participants on a screen. After explaining each scenario, the researcher asked whether they recognised the story, and why or why not, engaging in a dialogue and aiming to evoke relevant past experiences. Through questions, the researcher encouraged the participants to supplement the basic story with real life contents. As a result of this dialogue, stories revealing past driver experiences were elicited that enriched the researcher's understanding of the current context of driving.

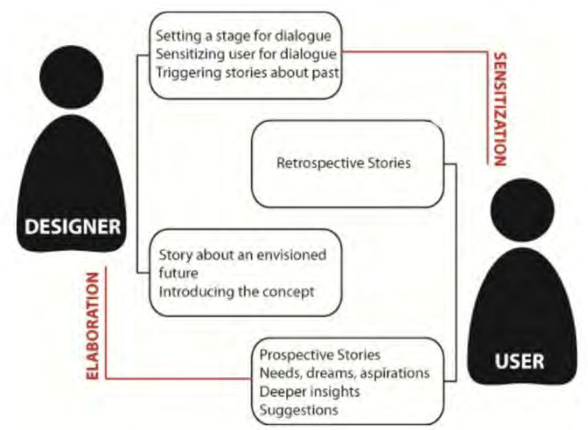

Figure 3.4 Phases of CoConstructing Stories interviews.

The second phase started with a 20-minute driving video in which the 30 ideas were presented. The participants were seated in front of a TV and watched a video showing a driving scenario. The video played until an image showing an idea appeared. Then the researcher paused the video and told the story about this idea presented in a popup on the screen. Each popup consisted of 3 layers (Figure 3.5): 1. Context layer, which is an image clipped from the video. 2. Visualised information layer, which shows the social information in a visually augmented way. 3. Elaboration layer, which is the textual description of each concept. After the explanation of the story, the researcher elicited positive and negative feedback about the concept by asking what the participants liked and disliked in the scenario, and why? With these questions, the researcher encouraged the participants to supplement the basic story about the concept with contents representing anticipated future driving experiences, based on their needs, dreams and aspirations. At last, they were asked to fill out a questionnaire with 7 points Likert scales (ranging from -3 to 3), for Useful, Pleasant and Interesting, and a summary scale for liking - the overall impression of the concept. The whole session lasted about forty minutes and was audio recorded. 22 participants attended the CoConstructing stories sessions. They were divided into two groups. Fifteen concepts were judged by group 1, and the other fifteen were judged by group 2, so that each of the 30 ideas was judged by 11 participants. All the participants were between 25-30 years old and had more than five years driving experience.

Figure 3.5 Three layers of information for each concept presented to participants

3.3 RESULTS

3.3.1 Analysis of quantitative data

For each idea, 11 participants gave ratings on four scales, Usefulness, Pleasure, Interest and Liking.

Correlations

To begin with, inter-scale correlations were calculated in SPSS to see whether the different scales represented different constructs. The overall correlations of the four-dimensional data were found to be all quite high (Table 3.2).

Table 3.2 The correlations of liking, usefulness, pleasure and interest.

		Usefulness	Pleasure	Interest	Liking
Usefulness	-	-	-	-	-
Pleasure	Person Correlations Sig. (2-tailed) N	.788** .001 11	-	-	-
Interest	Person Correlations Sig. (2-tailed) N	.881** .001 11	.816** .001 11	-	-
Liking	Person Correlations Sig. (2-tailed) N	.916** .001 11	.840** .001 11	.919** .001 11	-

**. Correlation is significant at the 0.01 level (2-tailed)

3.3.2 Descriptive statistics.

Figure 3.6 and Figure 3.7 and shows the average Usefulness, Pleasure, Interest and Liking score of the different concepts grouped by the categories of needs (some concepts that belong to 2 categories are included in both categories). All the concepts in the Safety group got positive scores (above 0.00) in Pleasure, Usefulness and Liking, but most of them got negative score (below 0.00) in Interest, which indicated that participants needed these concepts although they are not interesting. Almost all the concepts (12 of 13) in Efficiency group got positive scores in Pleasure, Usefulness and Liking; Most of the concepts in this group (10 of 13) got positive scores in Interest. The opinions for the concepts in the Relatedness and Identity categories fluctuate: 7 of 17 concepts in this group got negative scores in Pleasure and Usefulness, 6 of 17 got negative scores in Interest, and 4 of 17 got negative score in Liking. Most of the concepts (6 of 9) in Identity group got negative scores in Pleasure and Usefulness. More than half concepts (5 of 9) in this group got positive score in Interest and Liking.

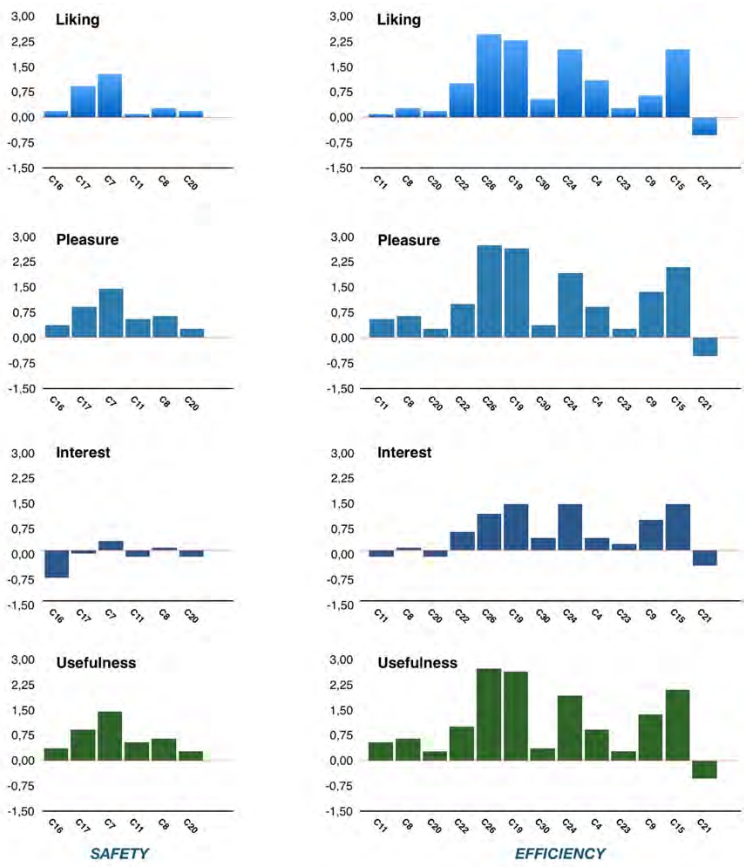

Figure 3.6 Average ratings for the individual concepts of Safety (left) and Efficiency (right) groups. Ratings range between -3 (minimum) and +3 (maximum). The average is based on ratings from 11 participants.

Descriptive data provide general feedback on the acceptance of all the concepts from different categories, but which factors influence people to evaluate the concepts? The CoConstructing Stories method elicits in-depth feedback that is specific to the concepts. Some cues emerged from the conversation between the researcher and the participants. There are several main factors that appear to influence participants' feedback of the concepts. For different levels of needs, people pay attention to a different side of the concepts.

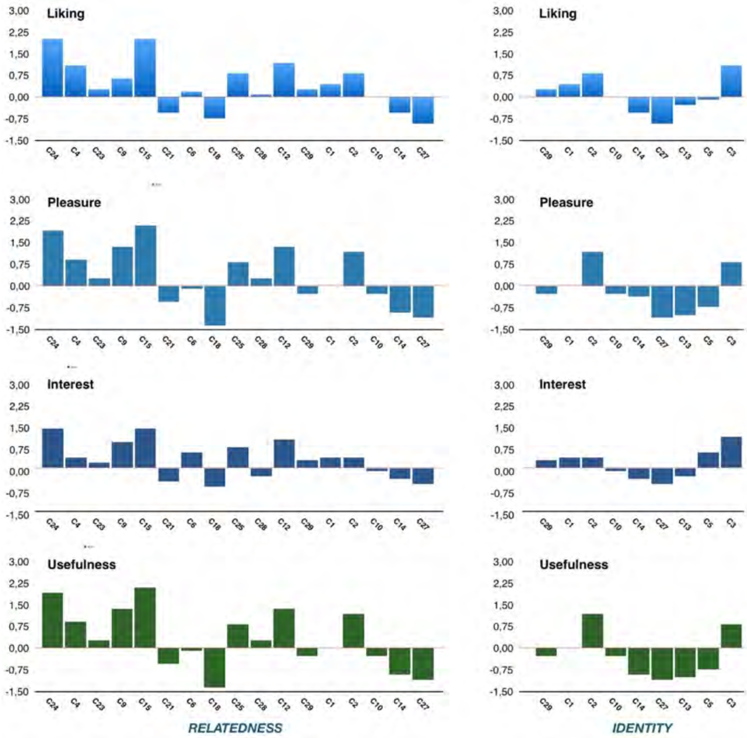

Figure 3.7 Average ratings for the individual concepts of Relatedness (left) and Identity (right) groups. Ratings range between -3 (minimum) and +3 (maximum). The average is based on ratings from 11 participants.

Feedback and observation

For Safety concepts, the participants appeared to have little tolerance of others' negative feedback. Receiving negative feedback while driving information was considered very frustrating, especially if it comes from other drivers. For instance, if we take concept No.16 ("People can remind other drivers to keep distance"), drivers would be angry to receive this feedback from other drivers but would be less sensitive if they could send the message themselves. In this category, encouraging, expressing appreciation and apology were considered more helpful to enhance on-road tolerance.

For Efficiency concepts, the participants cared very much about the simplicity of the information. They saw spending attention on road information as an investment. Only efficient solutions that appeared at the appropriate time gained acceptance. For example, concept No.19 ("People can get "gas discount" information when their fuel is low") got high value in liking. However, some complicated applications, such as concept No. 23 ("Driver can make travel plan with their friend when driving") gained less acceptance. Some participants said, "It is not the right place to discuss so complicated issue on the highway."

Figure 3.8 Top 6 concepts which gained most acceptances: Concept 26 "Ask for priority"; Concept 19 "Gas discount"; Concept 24 "Reason of traffic jam"; Concept 15 "Like the driving behaviour"; Concept 7 "Volumes down"; Concept 12 "Awesome Place".

With regards to the concepts belonging to the Relatedness and Identity categories, the Transparency and the type of Connection between drivers appeared to play a role. Transparency concerns the nature of the information that will be exchanged between drivers: with High Transparency, drivers share personal information such as restaurants they often visit and their driving skills, mood or emotion. With Low Transparency, the nature of the information is more impersonal, such as music they like. Usually, the social activity on the highway is a social activity between strangers. Maintaining this social distance was considered very important by the participants. Some less private information such as music taste (Concept No. 24), which prevents leaking personal information but conveys personal identity could be useful to establish a temporary relationship.

With respect to the type of Connection, existing Connection means whether drivers have certain characteristics in common, such as whether they work in the same industry or whether they have passed each other several times before; it should be noted, though, that the drivers may not be aware of this type of existing connection. No existing Connection refers to the cases where such common history does not exist. Inspection of the pattern of results indicated that participants did not like to interact with people with whom they shared no common points. Concept No. 27 ("Twitter message of nearby drivers can be displayed") gained a very low score. "I don't care about the people I don't know," some participants said. However, concept No. 2 ("You can get informed if a car nearby is from the same city and heading to the same destination as you") was more accepted by the participants. Moreover, most participants were not interested in strangers' expression of identity on the highway. They did not want to know the inner feeling of a stranger and considered the decoration of the strangers' car to be a distraction. On the other hand, for concepts involving sharing information between drivers between whom there was an existing connection, for example, if the personal feeling was sent by family or friends, participants were more positive about the concept.

3.4 DISCUSSIONS, CONCLUSIONS AND LIMITATIONS

We investigated which concepts for social interaction between drivers were considered useful, pleasant, interesting and liked by drivers. Liking was used as a summary rating. The Liking ratings revealed that the participants were mostly positive about the concepts belonging to the Safety and Efficiency categories.

As regards the concepts of the Relatedness and Identity groups, the results were mixed: some concepts were more acceptable while others were clearly rejected. Closer inspection of the pattern of ratings and the qualitative remarks suggested that for these categories additional factors needed to be taken into consideration. At least two such factors were identified: Transparency and the type of Connection between drivers. It appeared that concepts involving sharing High Transparency information were liked less because of privacy considerations. The absence of an existing Connection decreases the likelihood of a concept being liked: most participants were not interested in receiving information about strangers on the road, especially in the Identity category. The additional factors by no means provide a complete understanding of the pattern of like and dislike, for which further research is needed.

A collection of 30 concepts is a very small sample comparing with the countless applications on the highway in the future. Considering additional concepts may provide clues for additional factors and may help to formulate more precise hypotheses about factors influencing whether concepts will be considered useful and will be liked by drivers. Moreover, the scenarios considered were only highway scenarios. Concepts for other contexts such as urban environments will extend the research. Furthermore, the acceptance of applications depends on three distinct perspectives: utility, usability and cost (Fishbein & Ajzen, 1977). In this study, we only discussed utility.

In this chapter, various concepts were generated by brainstorming, categorised according to different levels of need and evaluated by CoConstructing stories method. The results of the evaluation may be used to identify criteria for selecting concepts for further investigation. However, our research is to investigate the influence of digital communication in driving context. These concepts should be further analysed from a more fundamental level. Therefore, in the next Chapter, a communication model is presented to analyse the social interaction between drivers from the perspective of information exchange, which allows categorising the social-car concepts in different dimensions.

4 Communication Model[1]

In the previous chapters, a framework of social communication between drivers was proposed, and 30 novel applications were generated and evaluated. In this section, we apply a *Four-sides model* (Schulz von Thun, 2008) to describe different dimensions of information exchange between drivers, which may be enhanced by the latest Vehicle to Vehicle communication technology. Under this model, four concepts were later developed and prototyped for further exploration to investigate digitally augmented social interaction between drivers.

4.1 FOUR-SIDES MODEL

In chapter two, we suggested a framework of communication between drivers enhanced by *locative mobile social networks (LMSNs)* and elaborated the characteristics of *synchronous-nearby* communication combining the digital and the physical layers. For further analysis of communication between drivers, and providing insights and guidance for

[1] Based on: Wang, C., Terken, J., Hu, J., & Rauterberg, M. (2016, October). Improving connectedness between drivers by digital augmentation. In Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications Adjunct (pp. 135-140). ACM.

future applications, we apply the *Four-sides model* (also called *Communication Square*) (Figure 4.1). This model was proposed by German psychologist Schulz von Thun (1981; 2008), which was based on the work of human communication by Karl Buehler (Griffin & McClish, 2011) and Paul Watzlawick (Bateson, 1972). According to this model, any message principally contains information on four sides: facts, self-revelation, relationship and appeal (Figure 4.1). We take an example to explain this model.

> *The wife is driving a car, they stop under a red traffic light. A moment later, the husband in the passenger seat says: "The light is green." Then the wife replies: "Who is driving, you or me ?" (Schulz von Thun, 2004)*

Actually, the husband acts as the transmitter (sender) of this message, "The light is green", which contains four sides of information:

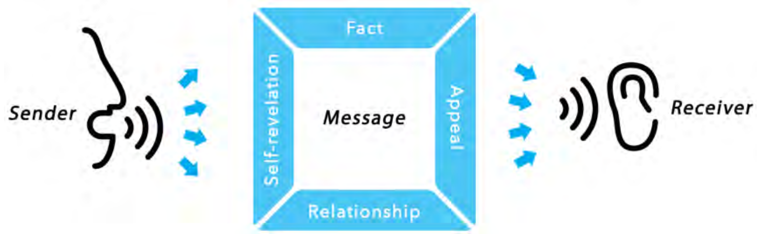

Figure 4.1 Four-sides model by Schulz von Thun (1981).

- ***The fact side (what I inform about).*** This side concerns factual information on objects, events, or people. It is the task of the sender to send this information clearly and understandably. "Factual information can be clearly recognised as true or false, be more or less significant to the matter, and provide full or incomplete knowledge" (Risius, 2014).
  In the example, we know the state of the traffic light – it is green.
- ***The self-revelation side (what I reveal about myself).*** This side concerns information about the sender himself. It can either be a voluntary form of self-presentation or an unintended self-revelation.

In the example, the message discloses that the husband sees the traffic light and feels hurry.

- *The relationship side (What I think about you and how we get along with each other).* This side concerns information about the sender's estimation of the receiver and his/her estimation of their mutual relationship. The sender may express esteem for example, respect, friendliness, disinterest and contempt.
  In the example, the message further reveals that the husband does not quite trust his wife's driving capability.
- *The appeal side (What I want you to do).* This side concerns information about an appeal to act. The sender wants to make the receiver to do or not to do something. The attempt to influence someone can be obvious, which is called advice; or hidden, which is called manipulation.
  In the example, the husband's message expresses a clear appeal to the wife: drive.

"Those four aspects of a message are equally relevant for the person talking and the person listening. It could be said that we talk with four mouths and listen with four ears" (St. Pierre, Hofinger, Buerschaper, & Simon, 2011, p.155). Which of the four sides the sender wants to emphasise is determined by his or her thoughts, intentions and communication abilities. In turn, there is a possibility for the receiver to hear intently on each side of the message. Which of these sides the receiver emphasises "will be rooted in his or her present mental state, expectations, anxieties, and in previous interactions with the sender" (St. Pierre et al., 2011). Therefore, it is difficult for the sender to predict the reaction of the receiver, as the sender cannot control listener' mind. In this case, the wife (receiver) has an especially sensitive "ear" for the relationship-side, and she defends herself by replying: "Who is driving, is it you or me?" However, this side might not be what her husband intends to emphasise.

In the driving scenarios, due to the limited bandwidth of the communication channel, some sides of information are hard to be conveyed or may even be misinterpreted. Conflicts often happen when one driver misunderstands another driver's intention. For example, when a driver is overtaken by a sports car with high speed, he receives the information in four sides (Figure 4.2)

- He perceives the fact that the car is driving fast.
- In the self-revelation side, he is acting in a diagnostic manner: "What type of person is this?" and "What is going on with him now?". Through the tinted window, the driver only sees a young guy is driving the car, and a young girl is in the passenger seat. "He just does it for fun!", the driver may think.
- He might be annoyed in the relationship side: "What does he think of me?" The driver may think that "he just sees me as an obstacle on the road".
- The appeal side might be evaluated under the question: "What does he want from me?" The driver may become angry because "He wants to scare me!"

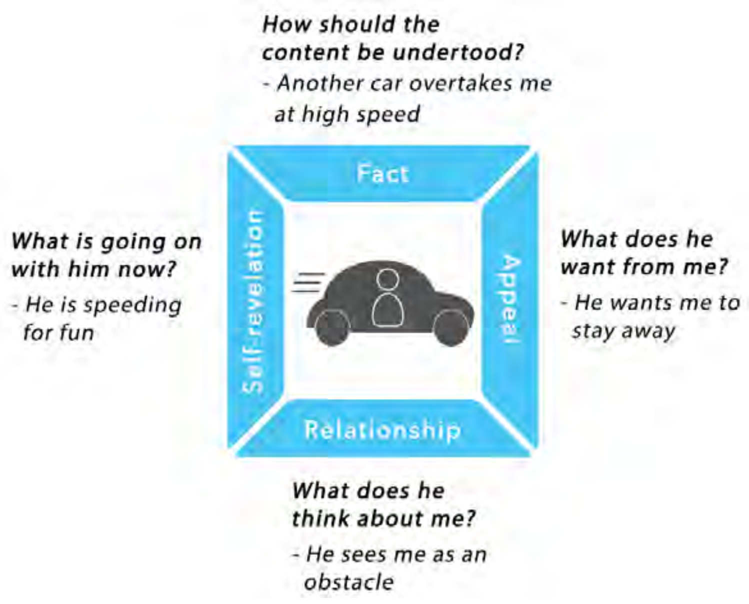

Figure 4.2 The driver receives the message (fast overtaken by another car) with "four ears" (based on Schulz von Thun, 2004) .

Thus, the misunderstanding emerges, which may result in dissatisfaction, aggressive behaviour or even road rage. However, it may be that the sports car's driver is just in a hurry taking his sister to the hospital and wants to apologise for the aggressive overtaking.

As suggested in chapter two, with the help of connectivity between vehicles, drivers can communicate with each other not only in the physical layer but also in the digital layer. The *four-sides model* can also be utilised for analysis of the computer-mediated communication (Risius & Beck, 2014). With this, we integrate the *four-sides model* into the framework of dual-communication between drivers for better understanding the mechanism of social interaction facilitated by digital augmentation (Figure 4.3).

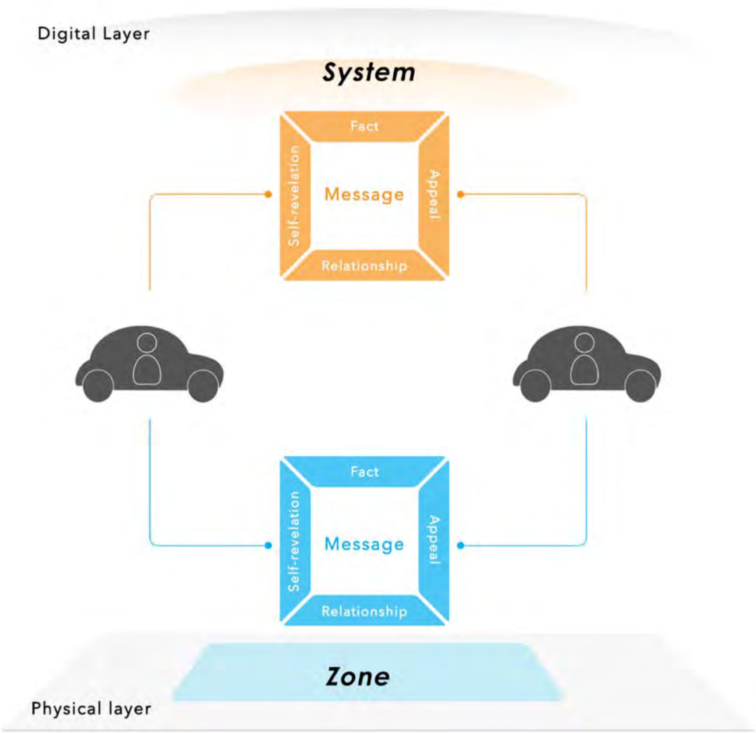

Figure 4.3 Communication between drivers in dual layers.

In *face-to-face* communication, the verbal information and non-verbal information may be complementary. For example, people may say "I am sick" with a sad facial expression. We suggest that the information sent through the physical layer (e.g. lights, horn, car-body languages) could be supplemented in the digital layer (e.g. social networks). The information which is conveyed by the digital layer could help drivers to emphasise one side of the communication square to enhance the quality of social interaction.

Let us take the example of misunderstanding of the overtaking behaviour between drivers mentioned above: If the sports car driver could reveal that he is taking his sister to the hospital in the digital layer (e.g. show the sign of “Sorry, in a hurry to the hospital”), then his intention may be interpreted completely in another way: For the self-revelation side, this message discloses the reason behind his hurry driving behaviour; For the relationship side, this message indicates that he sees other drivers are empathetic; For the appeal side, this message friendly asks for giving the way. As a result, the aggressive emotions of others might be decreased or even eliminated.

4.2 FOUR APPLICATIONS FOR FURTHER IMPLEMENTATION

In chapter two, the problems caused by the limitations of communication are elaborated, and a structured framework is proposed to interpret the forthcoming social communication between drivers. In chapter three, various concepts were generated by brainstorming, categorised according to different levels of need and evaluated by the CoConstructing stories method. In this chapter, a communication model is introduced to analyse the social interaction between drivers from the perspective of information exchange.

The research methodology of this thesis is to use novel applications as probes to evaluate the relationship between digitally augmented social interaction and the psychological and behavioural influences on driving through experiments. These applications were selected and developed from the novel concepts in chapter three. The criteria for selecting concepts were based on the conclusion of previous and this chapters:

- Firstly, our research goal is to mitigate conflicts on sharing the road and reduce social isolation. As a result, the selected concepts should address these two problems.

- Secondly, which is mentioned in Chapter 2, there is an untapped potential of *synchronous-nearby* applications, and our research mainly focuses on this category. Therefore, the concepts belonging to this category were preferred.
- Thirdly, the concepts which received positive feedback in the evaluation in chapter three have potential for further development.
- Fourthly, the novelty of the concept, in other words, whether a concept had appeared in previous research or applications, was another concern.
- Finally, to comprehensively investigate the influence of digital information on driving behaviour and experience, the concepts that were selected for further evaluation should emphasise different sides of the four-sides model.

Based on these criteria, seven concepts were selected:

- Concept 15 (Safety and Efficiency, the rating of Liking: 2): Imagine that if a driver gives you the way to pass, you can "like" his driving behaviour.
- Concept 26 (Efficiency, the rating of Liking: 2.4): Imagine that a driver whose child is seized with a serious sickness asks for priority on the emergency lane.
- Concept 8 (Safety and Efficiency, the rating of Liking: 0.0): Imagine your car can express your state: "I'm really in a hurry!"
- Concept 28 (Relatedness, the rating of Liking: 0.0): Imagine that there is a platform for drivers to post some information on the road, and you can get filtered information that is relevant to you.
- Concept 29 (Relatedness and Identity, the rating of Liking: 0.2): Imagine that a car smiles to you, because it is 10th time you pass each other on the highway. Moreover, you can get to know each other
- Concept 3 (Identity, the rating of Liking: 1.0): Someone can show the music that he is listening to to other drivers nearby.

- Concept 6 (Relatedness and Identity, the rating of Liking: 0.1): Imagine that you can send a music track to the front car as a gift.

According to the feedback of the evaluation in Chapter 3, they were modified and merged. Finally, four applications were developed and elaborated. They are:

"*Likes/Dislikes*", based on Concept 15 - This application holds that "You can give other drivers around you a "Like" according to their good driving behaviour". In this application, the "Likes" provide the evaluation on people's behaviour in real time. It encourages people to drive politely. Therefore, this concept emphasises the **appeal-side**. According to the feedback of the participants in study 1 of Chapter 5, the "Dislike" feature was added.

"*CarNote*", based on Concept 26, combined with Concept 8 - This application holds that "A driver can publish his special driving status, such as 'in a hurry to the hospital'". In this concept, the "hurry" status discloses information about the driver as an explanation for his behaviour on the road, emphasises the **self-revelation-side**.

"iSticker", based on Concept 28, combined with Concept 29 - This application holds that "A driver can show his identity by a virtual sticker to others who are in the same community"; and *"MusicHound"*, based on Concept 3, combined with Concept 6 - This application holds that "A driver can share the music he is listening to with surrounding drivers who have the same music taste". Revealing drivers' liking of sticker and music is obviously self-revelation information. However, our goal is to establish social bonding between drivers. The key feature of these concepts is that only the drivers who like the similar stickers and music can see each other. As a result, the stickers and music express group affiliation to other community members, which emphasises on **relationship-side**.

Likes/dislikes provides feedback and raises social awareness, while *CarNote* reduces misunderstanding and strengthens empathy, they aim to enlarge the communication bandwidth between drivers. The other two, *iSticker* and *MusicHound* aim to enhance social closeness through delivering relationship information. They aim to reduce the anonymity on the road. All the concepts were further prototyped on a driving simulator. Then user tests were conducted to evaluate their acceptance, and whether these concepts exert a positive influence on driving behaviour and experience. This way, our research covers all sides of four-sides model.

5 Mitigating Driving Aggression through Sending/Receiving Appeal Information[1]

In chapter three, novel “social car” ideas were discussed. The “Liking other drivers’ behaviour” emerged as one of the most promising concepts. In

[1] Based on:
Wang, C., Terken, J., & Hu, J. (2014, September). Liking other Drivers' Behaviour while Driving. In Adjunct Proceedings of the 6th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (pp. 1-6). ACM.

Wang, C., Terken, J., Yu, B., & Hu, J. (2015, September). Reducing driving violations by receiving feedback from other drivers. In Adjunct Proceedings of the 7th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (pp. 62-67). ACM. This paper received the “Best Poster Award“ at the conference.

this concept, “You can give other drivers a ‘Like’”, which emphasise information on appeal side. In this chapter, this concept is explored in more depth with a driving simulator study. Three rounds of evaluation are presented. The result shows that the system positively influences people’s driving behaviour and the concept is accepted by most participants.

5.1 AGGRESSIVE DRIVING

Aggressive driving may be defined as any driving behaviour that intentionally endangers others psychologically, physically, or both (Ellison-Potter et al., 2001). Evidence both from the literature and news headlines suggests that aggression occurs among motorists on a regular basis (DCPC, 2005). A survey by the Automobile Association Britain shows that 90% of respondents reported that they had been involved in a “road rage” incident in the previous year (Byrne, 2000). In another study, Underwood et al. (Underwood, Chapman, Wright, & Crundall, 1999) found a link between anger and subsequent near accidents. It was also reported by Parker et al. that intentional aggressive driving behaviour makes a significant contribution to involvement in traffic accidents (Parker, Manstead, & Stradling, 1995).

5.2 CAUSES OF AGGRESSIVE DRIVING

Understanding the causes of aggressive driving is essential for effective intervention. Therefore, a variety of explanatory models of aggressive driving have been proposed (Brewer, 2000; Wright, Gaulton, & Miller, 1997). However, insufficient attention is paid in each of these models to the distinction between the interpretation of “triggering events” and the response to those events. In a report of the drugs and crime prevention committee of the state of Victoria, Australia (DCPC, 2005), a more complete model was proposed (Figure 5.1). In this model, all aggressive driving behaviour starts from a “Trigger”, such as being stuck behind a slow driver. Acts of violence are precipitated by the “triggering event”, but

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Wang, C., Terken, J., Hu, J., & Rauterberg, M. (2016, October). Likes and Dislikes on the Road: A Social Feedback System for Improving Driving Behaviour. In Proceedings of the 8th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (pp. 43-50). ACM.

more important is the interpretation of the triggers. Four kinds of factors, which are person-related, situational, car-related and cultural factors, influence not only the interpretation of the "Trigger" but also people's response to the "Trigger". At last, the outcome (commit aggressive behaviour or not) is determined by all the factors.

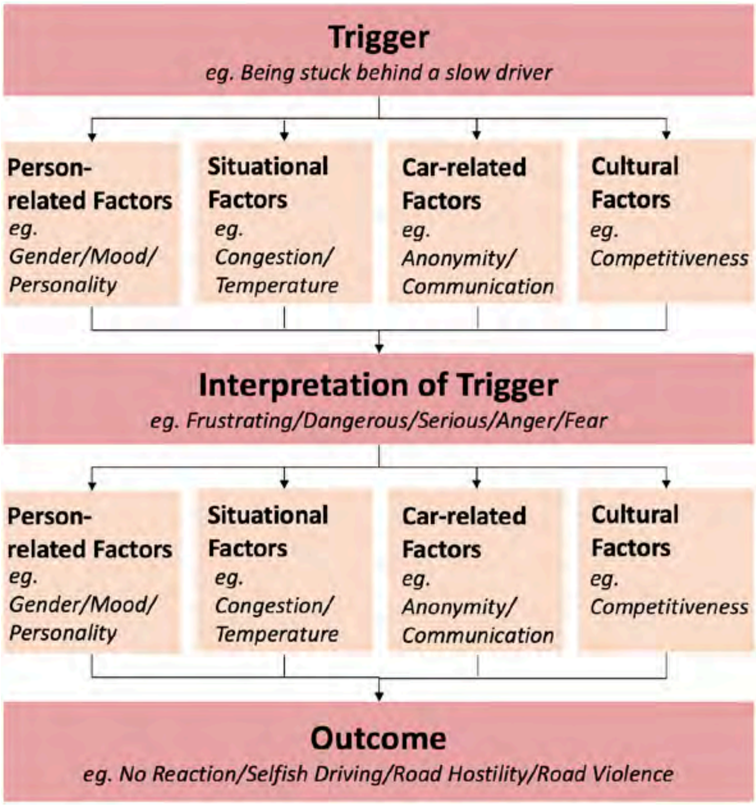

Figure 5.1 Causal model suggested by the report of the drugs and crime prevention committee of the state of Victoria, Australia (DCPC, 2005).

5.3 CAR-RELATED FACTORS OF AGGRESSIVE DRIVING

Many attempts were considered for addressing the problem of aggressive driving from the perspective of Car-related factor, as it is essential and more feasible for technique solutions comparing with other factors. Two aspects of the car itself that play a part in causing aggressive driving are mostly mentioned in previous research (Byrne, 2000; Teitell, 1996): *communication difficulties* and *anonymity* on the road.

5.3.1 Communication difficulties

Aggressive behaviour may occur because of the difficulties road users have in unambiguously communicating with each other (DCPC, 2005). Firstly, the physical distance between the road users makes it difficult to obtain full information about an action. Secondly, problems may arise because of the difficulty the drivers have in communicating their anger or frustration to other road users. The difficulty in conveying disapproval and expressing their emotion can make the conflict to escalate directly to a violent action. Thirdly, the isolating nature of cars can also make it difficult to apologise for errors made while driving.

5.3.2 Anonymity

The vehicle design (metal frames, tinted windows) provides a feeling of anonymity (P. A. Ellison et al., 1995). From the perspective of perpetrators, the anonymity offered by the structure of cars, as well the ease with which the perpetrators can usually escape from the scene of violence, has been widely cited as one of the main factors influencing the decision to act violently on the road (P. A. Ellison et al., 1995; Shinar, 1998). From the perspective of victims, the physical structure of vehicles induces a tendency to depersonalize other drivers. For example, instead of thinking of another driver as a mother of young children on her way to visit her dying father in hospital, they may simply be thought of as a “blue Fiesta” being driven by a total waster (Byrne, 2000).

5.4 RELATED WORK

5.4.1 Mitigating aggressive driving by connectivity between vehicles

Many attempts have been made to address the problem of aggressive driving from the perspective of car-related factors, as it is more feasible for technical solutions comparing with other factors.

In 2003, the Department of Transport (DoT) in the Netherlands launched the trial of the system “Belonitor” (Mazureck & Hattem, 2006). In the test, 65 lease cars were equipped with a device that records speeding and tailgating. Participants who drove properly were rewarded. The data obtained from surveys, interviews and the in-car system show that the real-time feedback and afterward rewarding have a very strong positive effect on safe driving behaviour. These systems aimed to improve driving behaviour by providing real-time feedback to drivers from the system or using external rewards, but not by enlarging the communication channel between drivers.

There have been several attempts to enhance social communication by conveying messages physically. In 1990, a Belgian insurance company aimed at reducing road aggression by giving their members two plastic hands – a red “I’m sorry” hand and a green “go ahead” hand – to be used when a driving error was made (DCPC, 2005). At the 2001 Tokyo Motor Show (PiquetFW11, 2015), Toyota displayed a car capable of warning other drivers of the driver’s mood by the colour of LED lights on the bonnet. The light display was intended to warn people how to react to approaching vehicles. However, using a physical communication method limits both the quality and quantity of information.

With everywhere available connectivity and the broad penetration of social network services, the communication between drivers on the road may change fundamentally. Firstly, quality and quantity of information may be transferred with little limitation, which may reduce the misunderstanding. Secondly, information may be delivered to a specific driver, without distracting other drivers who are not concerned. Finally, staying anonymous becomes difficult, the behaviour of road users may be traced by sensors, evaluated by systems and stored in the cloud.

This trend has drawn attention from both the industry and academia. For example, Lexus unveiled the concept car LF-FC at the 2015 Tokyo Motor Show (Lexus, 2015a), which enables the driver to send a pre-set message such as “After you” to nearby drivers by gesture. Schroeder et al explored the possibility of reducing driver aggression by humanizing cars and representing other drivers’ eye gaze and head pose through overlaid human-like avatars (Rakotonirainy et al., 2008). The experiment in a driving simulator showed that their approach had the potential to improve social interactions between drivers, allowing clearer collective decision making between the road users and reducing the incidence caused by antisocial behaviour on the road environment. Although some attempts for reducing aggressive driving by the latest V2V technology were proposed, so far, there is no systematic solution and related validation to address this problem under a theoretic framework.

5.5 CONCEPT AND RATIONALE

According to the intervention strategies to counter aggressive driving mentioned above, in this chapter, a social feedback system for improving driving behaviour by enhancing communication between drivers is suggested and an evaluation is presented, for the purpose of exploring the possibility of solutions based on new technologies. The system is based on the concept of “Liking other drivers’ behaviour” which emerged from interviews presented in chapter 3. The concept suggested that “Imagine that if a driver gives you the way to pass, you can ‘like’ his driving behaviour.” This concept enlarges the communication channel between drivers. Sending “Like” may be used to express the appreciation of good driving behaviour, which may cultivate polite driving habits.

5.6 STUDY 1: SENDING “LIKE”

We designed a gesture based interaction system for this concept and developed a prototype integrated in a driving simulator, which enabled drivers to send “Like” to other drivers if they appreciated the others’ driving behaviour.

5.6.1 Interaction design

The current in-vehicle human-machine interface (HMI) is shaped to operate traditional in-vehicle tasks such as navigation, entertainment and phone calls (Schroeter et al., 2012). But in our case, the HMI system must enable drivers to interact with surrounding cars to accomplish social interaction. There is no current interaction system to operate in such scenarios. However, the gestural interaction of POI (point of interest) which recently has become a hot topic in the in-vehicle HMI research domain can provide many significant references as it also requires direct interaction with the environment (Riener, 2012).

The use of gestural interfaces for in-car interaction can reduce visual demand and thus increase safety (Riener, 2012). The advantage of gestures is that it does not require physical interaction with another surface (Fujimura, Xu, Tran, Bhandari, & Ng-Thow-Hing, 2013). This topic has been researched by academia and industry for many years. Althoff et al. (2005) investigated 17 different hand gestures and six different head gestures, and used them for complex interactions with the in-car infotainment system to increase the expressive power of gestures. Mahr et al. (Mahr, Endres, Müller, & Schneeberger, 2011) designed a reduced set of three micro-gestures, which could be applied while keeping the hands on the steering wheel.

Gesture is a natural way to refer to physical items in the environment (deictic gestures) as well as a way to express spatial and physical relationships (iconic gestures) through relative hand positions and the trajectory of hand motions (McNeill, 2008). Rümelin et al. (Rümelin, Marouane, & Butz, 2013) investigated pointing as a lightweight form of gestural interaction in cars. They made a prototype that was able to recognize driver’s pointing to objects outside the windshield by a depth camera. After a series of experiments, a recognition rate of 96% was achieved in the lab. In their system, the driver’s hand had to remain in a stable position until the system confirmed the pointing operation by audio feedback. The results showed that the shorter the hold time, the higher is the tolerance of users. The feedback on using these gestures for the task of selecting an object in a street was positive. Fujimura et al. (2013) proposed a system for driver interaction with the environment by pointing to an outside target while maintaining a grasp on the steering wheel, combined with visual feedback in the form of a 3D Head-up Display (3D-HUD). However, their pointing gesture did not provide more semantic information than tip the objects in the environment. Further operations were needed to finish a concrete task.

5.6.2 Procedure of “Liking” operation

In our study, the main task of the application is to convey appreciation to a target car nearby. For this purpose, we designed an interaction flow which combined selecting target and conveying a “Like” operation in one gesture, and give drivers clear visual feedback by an augmented reality display.

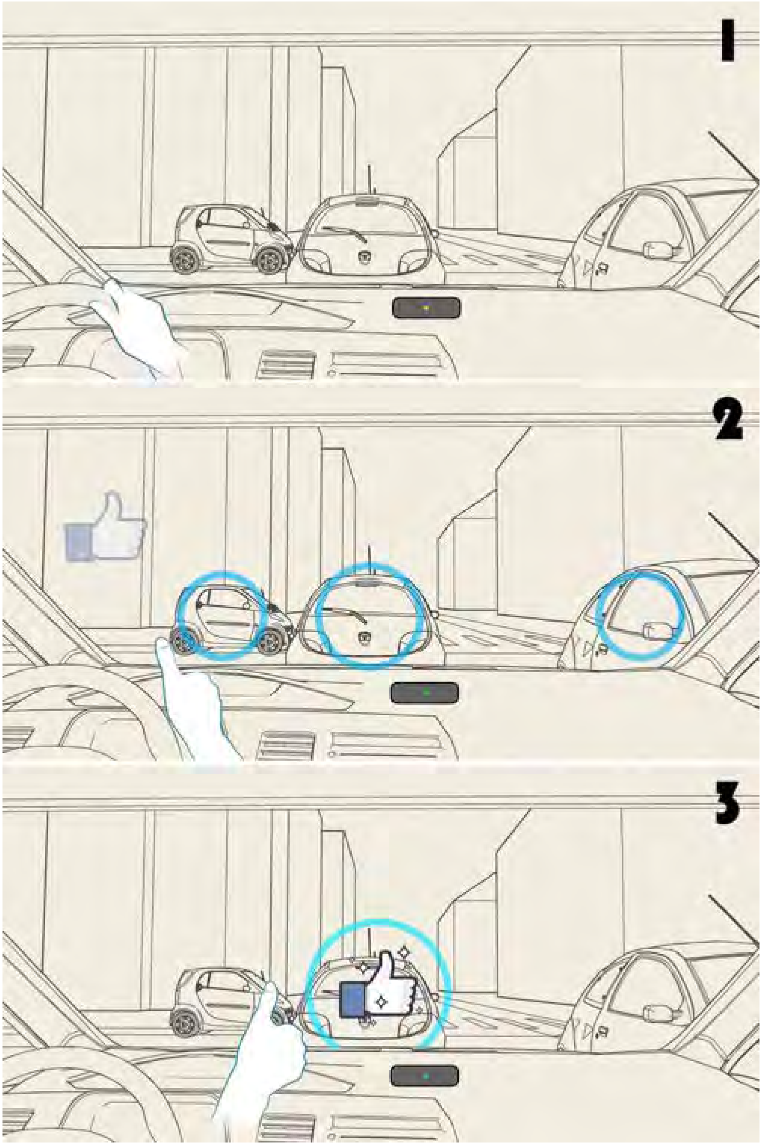

Figure 5.2 Procedure of "Liking" operation. Step 1: Normal driving status; Step 2: Stick out the thumb; Step 3: Point at the target and straighten arm.

The procedure of the "Like" operation can be divided into 3 steps (Figure 5.2):

- Step 1: The driver is in the normal driving status. When the gesture sensor does not detect any gesture other than manipulating the car, the HUD is on standby or displays primary driving information such as speed and navigation.
- Step 2: The driver wants to give another person's driving behaviour a "Like". He releases one hand from the steering wheel, sticks out the thumb to give the target car a "Like". This activates the Head-up Display (HUD), displaying several circles tagging cars nearby, and a thumb icon acting as a cursor to show his hand's relative position.
- Step 3: The driver points at the target car with his thumb and straightens his arm to confirm the "Liking" operation. The system recognizes this action and gives visual and audio feedback.

5.6.3 Apparatus

A setup integrating a gestural sensor and projector with a driving simulator was created to evaluate the concept. The driving simulator system included a steering wheel, seat, pedals, gears and six 17" screens (Figure 5.3).

In this study, we used a Leap Motion Controller, which is fixed on the steering wheel to track participants' gestures. The simulator computer transfers coordination data of the positions of nearby cars to an external laptop in real time, and the laptop projects the UI graphics directly on the simulator screen through a high-power projector. The application running on the laptop was developed using Processing language[1]. A video recorder was set behind the driver to record the whole process for further analysis. Figure 5.3 shows the 3 components of the gestural interaction prototype in the driving simulator.

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[1] https://www.processing.org

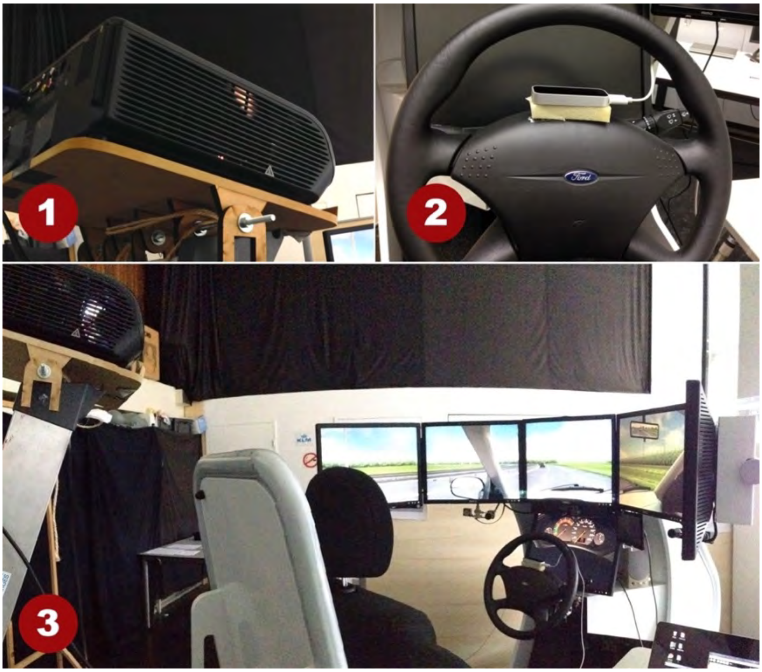

Figure 5.3 Setup of gestural interaction prototype based on driving simulator: 1. The high-power projector; 2. Leap motion fixed on the steering wheel; 3. Driving simulator.

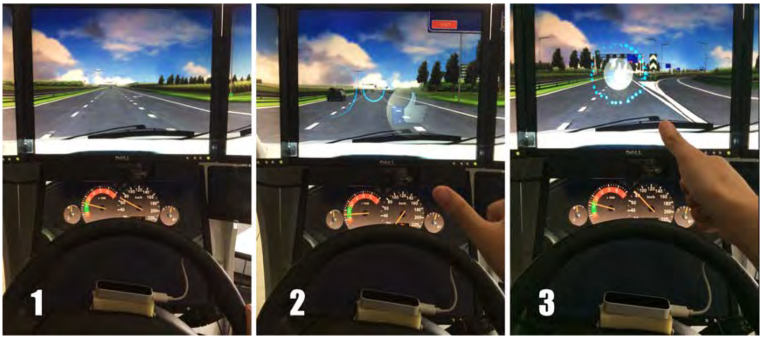

Figure 5.4 Implementation of the interaction design in the driving simulator

5.6.4 Experimental design

Ten participants (7 male, 3 females; ranging from 26 to 30 years with mean 27.6, all with more than 5 years driving experience), took part in the test. Firstly, they were introduced to the topic of the study. Then, they received 15 minutes of training to get familiar with the driving simulator. The testing scenario was a straight highway with 3 lanes. They were asked to wave their hands, stick out their thumbs and give random cars a "Like" while driving. After that, a bundle of tasks was given: 1. The participants were required to follow a car whose speed was 110km/h on the highway and keep a distance of 250 meters. Then they were asked to change the distance to 200m, 150m, 100m and give the front car 3 "Likes" respectively at these distances. 2. They were asked to overtake the front car in the left lane. When they were approaching the slower car at the distance of 50 meters, they were asked to give him a "Like". 3. They were asked to return back to the slow lane, slow down and wait for the overtaking of the behind car and give it a "Like" at the distance of 30 meters. Each participant finished the three tasks as described above five times. Afterwards, the NASA TLX (Task Load Index) questionnaire (Hart & Staveland, 1988), the System Usability Scale (SUS) (Brooke, 1996) and the AttrakDiff questionnaire (Marc Hassenzahl & Monk, 2010) were completed. And an interview was conducted to capture problems, preferences and general feedback.

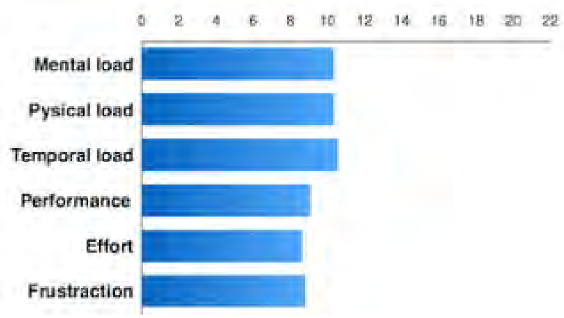

Figure 5.5 Subjective Workload (by NASA TLX questionnaire)

5.6.5 Results

Subjective Workload

NASA Task Load Index (NASA-TLX) is a subjective, multidimensional assessment tool that rates perceived workload in order to assess a task's, system's, or team's effectiveness or other aspects of performance, which was developed by the Human Performance Group at NASA's Ames Research Centre (Hart & Staveland, 1988). In this study, workload of performing gestural interaction was rated by the NASA-TLX. According to the NASA TLX, ratings for all six dimensions were low to medium (Figure 5.5).

Usability

System Usability Scale (SUS) is a low-cost usability scale that can be used for global assessments of system usability (Brooke, 1996). In this study, the perceived usability was assessed with (SUS). The total score was 73.5 (ranges from 0-100), which is located in the "acceptable" to "good" range according to a data analysis of 2324 surveys (Bangor, Kortum, & Miller, 2008).

Figure 5.6 Result of Attrakdiff

User Experience

AttrakDiff is helpful to evaluate the Hedonic quality (HQ) and Pragmatic quality (PQ) of this system. The results of AttrakDiff showed that the system was rated as fairly positive both in terms of hedonic and pragmatic quality (Figure 5.6). The overall impression of the product is very attractive, but there is room for improvement in terms of hedonic quality as well as usability.

Feedback from participants

Participants evaluated the concept quite positively, as evident from the positive scores both for hedonic and pragmatic quality. Interestingly, more than half of the participants wanted to have a “Dislike” function added. Participants commented that the main source of distraction was the visual feedback. Many participants complained that it blocked their sight. Some participants suggested moving the visual feedback to the top of the target car as the sight on the road should always be clear. Furthermore, all the participants said that the “Like” gesture was very intuitive and easy to remember.

5.6.6 Discussion

Mapping gestures with visual feedback

Fujimura et al. (2013) divide the communication in their system (combined gesture and 3D-AR display) into two perspectives: Allowing the driver to input information and providing feedback to the driver. In our study, participants provided input with the “Like” gesture, which was recognized by the Leap Motion sensor; feedback was provided with an augmented “Like” icon acting as a cursor that was projected on the simulator screen. A more natural way is to remove the “Like” cursor and enable driver to use hands to interact with other cars directly. However, that may cause another problem in a driving context: The focal plane of the user’s thumb is different from the focal plane of the targets, which may increase visual distraction and decrease the accuracy of selection.

Semantics and learnability

According to the feedback from the participants, the “Like” gesture was very intuitive and easy to remember. This was consistent with two items in the SUS questionnaire that could reflect learnability. Besides, they were also familiar with the thumb icon that was projected on the screen as it is widely used in social media such as Facebook and Instagram. However, one participant argued that if there were many applications in the future, different gestures might be needed to control different applications, so that people might have to remember lots of different gestures. A better solution could be a single gesture might apply to several applications and the system might comprehend the semantics based on the context. For instance, the system may be able to recognize not only sticking your thumb but also waving your hand to others as “Like” operation. In other contexts, sticking your thumb and waving your hand might stand for “confirm” and “cancel” commands.

5.6.7 Concluding remarks of study 1

In this study, we have evaluated a concept by which drivers may provide positive feedback about the driving behaviour of other drivers. We found that the concept was appreciated by the participants, as evident from a positive score for hedonic quality in AttrakDiff. Also, we investigated a gesture based interaction design for the concept. It showed that gestural interaction combined with augmented reality visual feedback, enabled the drivers to express appreciation for others’ driving behaviour with limited workload and acceptable usability.

We did not evaluate matters such as task completion time, error rate and visual distraction. Also, the influence on driving behaviour was not analysed and the sample size was small. Furthermore, the interaction is only one of the factors that influences the acceptance of the system. More importantly, being able to “Like” other drivers’ behaviour implies that, changing the perspective, our driving behaviour may be “Liked” by other drivers. As a next step, we will change the perspective and investigate how drivers feel about receiving feedback evaluating their driving behaviour from other drivers.

Figure 5.7 The GreenDino Simulator.

5.7 STUDY 2: RECEIVING "LIKES/DISLIKE"

With respect to sending "Like" on the road, the results of the previous evaluation of the prototype based on gesture interaction demonstrated that drivers were able to give specific drivers real-time feedback of their driving behaviour. But whether feedback from other road users will exert positive influence on people's driving behaviour is still unknown.

In study 2, we changed the perspective and investigated how drivers felt about receiving feedback from other drivers to evaluate their driving behaviour. Besides, in the first study, more than half of the participants suggested to add the "Dislike" feature. Therefore, "Dislike" was also included in this study.

Figure 5.8 An eight-inch screen was installed in front of the steering wheel to show other driver's Like/Dislike feedback.

As a result, we tested 2 hypotheses:

- H1: The presence of real time feedback has positive influence on driving behaviour. It is predicted that the participants' driving behaviour improves according to both objective and subjective evaluations.

- H2: Dual feedback (positive + negative) and only positive feedback exert different influence on driver's behaviour. It is predicted that driving behaviour data are statistically different.

Figure 5.9 A virtual dashboard, including speed metre, rpm metre and a turn-by-turn navigation, was displayed in the TV.

5.7.1 Methodology

Apparatus

A setup integrating an eight-inch screen and an advanced driving simulator was adopted to evaluate this concept (Figure 5.8). The GreenDino's driving simulator[1] included a steering wheel, seat, pedals, gears and three 42 inch screens (Figure 5.7). There was a virtual dashboard with the speed and RPM metres, and a turn-by-turn navigation displayed in the TV (Figure 5.9). When the participants were driving in the simulator, the driving view was also displayed on the screen in another room, enabling the "observers" to observe the driving behaviour and giving evaluative feedback about participants' driving behaviour. If the observer clicked the "Like" or "Dislike" icon on the screen of a laptop that was

[1] http://www.greendino.nl/home-en.html

connected to the eight-inch screen in front of the participant, the corresponding icon (see Figure 5.8) appeared on the screen of the participant to inform him though visual and sound feedback.

Scenario

A highway scenario that included curves, viaducts, entrance ramps and exit ramps, along with high density of traffic was created for testing. Eleven of the other vehicles in the scenario were programmed to behave impolitely in three ways: Four vehicles drove very slowly on the overtaking lane, five changed lane suddenly and two vehicles merged in from ramps aggressively.

Participants

A within group test, which involved 18 participants (16 males, 2 females; ranging from 21 to 32 years with mean 24.5, all with more than 3 years driving experience), was conducted in this study. The participants did not get paid in this study.

Criteria of evaluation

One observers, who was not related to this research topic, acted as "other road drivers" evaluating the participants' behaviour from a monitor. The observer was not aware of which condition the participants were allocated to. The observer gave "Like" and "Dislike" in a separate room without seeing participants' face. The standard of negative and positive evaluation was created based on "20 most annoying driving behaviours" in the survey conducted by the Consumer Reports National Research Centre in January 2012 ("2012 Annual Auto Issue: Survey reveals top gripes among drivers," 2012). The observer applied the following criteria:

For evaluating behaviour as "dislike"

- Tailgating
- Cutting off other cars
- Speeding and swerving in and out of traffic
- Not letting others merge into a lane
- Not using turn signals
- Driving slowly in the passing lane
- Overtaking from right side (which is prohibited in the country where this research was conducted)

For evaluating behaviour as "Like":

- Giving space to others merging into the highway by changing to the overtaking lane
- Reducing speed gently
- Letting fast car overtake
- Keeping distance to front vehicle when they reduce speed

Besides the observers' judgments, an objective assessment of the driving performance was conducted. To this end, GreenDino's driving simulator generated 41 kinds of basic driving quality scores by analysing the driving behaviour (sampled at a frequency of 10 Hz). Five scores were chosen for evaluating the driving performance (further explained under Results).

Procedure

Each participant was first invited to drive on the simulator in a free driving mode for 30 minutes with the purpose of getting familiar to the driving simulator. The participant was then introduced to the concept of the driving behaviour credit system. The participants were asked to assume themselves driving under the condition: "You are driving to meet a client in an unfamiliar city. It's a little late. Unfortunately, you encounter heavy traffic on the highway, so follow the navigation system and drive as fast as you can."

All the participants were asked to complete three driving tasks, each lasting 15 minutes. The observer evaluated the behaviour as "Like" and "Dislike" if certain behaviour caught attention. The observer gave and recorded "Like" and "Dislike" in all three conditions, even though participants received this feedback only in two of them: In the "Like + Dislike" condition, they received "Like" and "Dislike" feedback in real time; In the "Like only" condition, they received only "Like". In the "No feedback" condition, they received no feedback. Our concept encourages people to express positive feedback. The negative emotional expression may lead to aggressive behaviour per se (Lajunen & Parker, 2001). For this reason, the experiment condition with only "Dislike" feedback was not included in this study. The sequence of the tasks was randomized to balance against carry-over effects. An interview was conducted after they finished all the tasks. The numbers of "Likes" and "Dislikes" and the driving behaviour data were collected by the driving simulator.

5.7.2 Results

Repeated measures ANOVA (RM-ANOVA) was conducted to compare their social driving behaviour, according to the subjective evaluation from the observer and the objective driving behaviour data generated by the driving simulator, in three conditions: (i) no feedback; (ii) “Like” and “Dislike” feedback and; (iii) only “Like” feedback.

Numbers of “Dislikes” and “Likes”

Figure 5.10 shows the mean of received “Dislike” and “Like” in three conditions. There was a significant difference in the number of “Likes” (F (2,18) = 5.104, p = 0.018) and “Dislikes” (F (2, 18) = 4.791, p = 0.021) that participants received in the three conditions. For “Like”, there was a significant difference between the group of no feedback and the group of only receiving positive feedback (p = 0.023), but there was no significant difference between “No feedback” and “Like + Dislike” groups (p = 0.168), neither between “Like + Dislike” and “Like only” (p = 0.81). For “Dislike”, there was a significant difference between “Like only” and “No feedback” groups (p = 0.019), as well as between “Like + Dislike” and “No feedback” (p = 0.032). However, there was no difference between “Like + Dislike” and “Like only” (p = 0.275). This indicated that drivers behaved more politely when they got feedback.

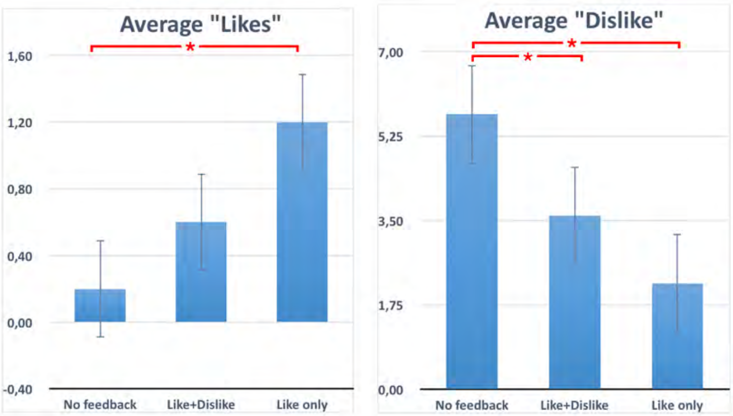

*Figure 5.10 Average “Likes” and “Dislike” allocated in three conditions. * indicates significance.*

Objective driving behaviour data

GreenDino's driving simulator system generates 41 kinds of scores. Five of them were related to safe driving performance and the criteria of "20 most annoying driving behaviours", were selected for objective evaluation of social driving performance. They are: *Keeping safe speed*, which measures speeding behaviour; *Position inside lane*, which measures incorrectly using the road; *Smooth braking*, which measures tailgating and driving too fast; *Smooth steering*, which measures aggressive cutting in, swerving in and out of traffic; And *Keeping distance to other cars*, which measures tailgating and aggressive cutting in. Figure 5.11 shows the framework of the driving performance.

Each value ranges from 0 to 10 and a higher value indicates better performance. Each score ranges from 0 to 10 and a higher value indicates better performance. The social driving behaviour was measured with the average of the five items. Figure 5.12 shows the mean of all the scores. The mean of driving performance with feedback is higher than no feedback. However, the objective driving performance in the three conditions falls short of being significant: $F(2, 18) = 3.463$, $p = 0.053$.

In-depth interview

In order to also get further feedback about this system, in-depth interviews were conducted after the experiment. Participants were asked several questions about their opinions of the influence on driving and whether they would be willing to use such a system.

All participants were willing to express their anger and appreciation to other road users and receive others' evaluation as well. Many participants suggested that a mechanism should be established to prevent abuse of "Dislike". Further punishment（e.g. related to insurance fee） and rewarding policies were suggested, but comparing to finance means, a few participants preferred "softer" solutions such as virtual badges on social networks.

When asked about whether they would improve their driving behaviour when they got "Dislike", most of the participants said they were more careful after receiving negative feedback and this did not infuriate them.

"I am not angry about other's evaluation. They remind me to take care of my safety".

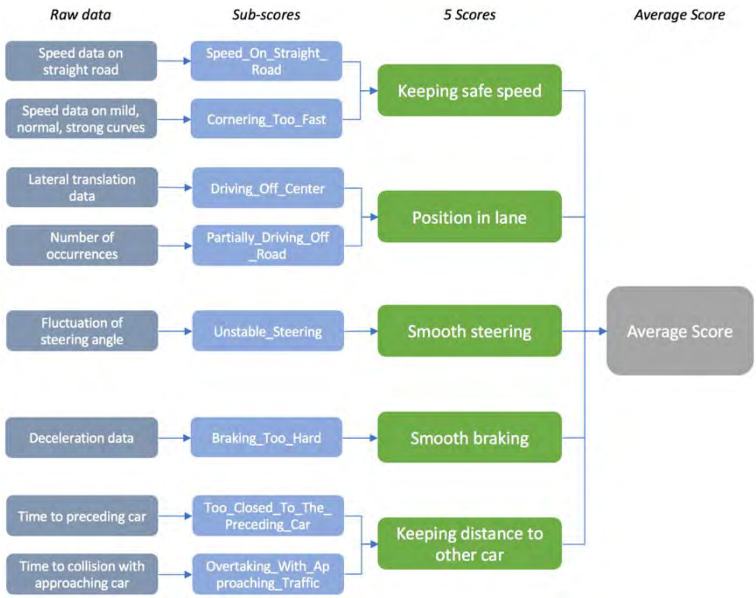

Figure 5.11 The framework of the evaluation of objective driving performance. 5 scores were the average of sub-scores, sub-scores were based on the analysis of the raw data. There were different strategies for GreenDino simulator to analyse the raw data. For example, the sub-score "Partially_Driving_Off_Road" was based on the number of occurrences of one-wheel driving off road. "Speed_On_Straight_Road" was a continuous score only based on how much he exceeds the limited speed on the segment of road.

One of the participants thought that showing other driver's behaviour would exert a positive influence on him. "Maybe I will be better if I know I got much more bad feedback than average, especially after showing me some demonstration of the correlation between this and accident rate".

Most participants reported that they were not able to realize the reason of getting each "Like" and "Dislike". "*I need more information to know what happened. For example, video recordings and driving data*". Furthermore, three participants thought that receiving evaluation in real time, especially negative feedback, distracted their driving. They preferred to obtain feedback afterwards.

As regards the impact of “Like” and “Dislike” on their driving behaviour, about half of all participants said they drove more carefully in order to get the “rewarding” from others. “*I have tried very hard to get a “Like”. It makes me happy!*”.

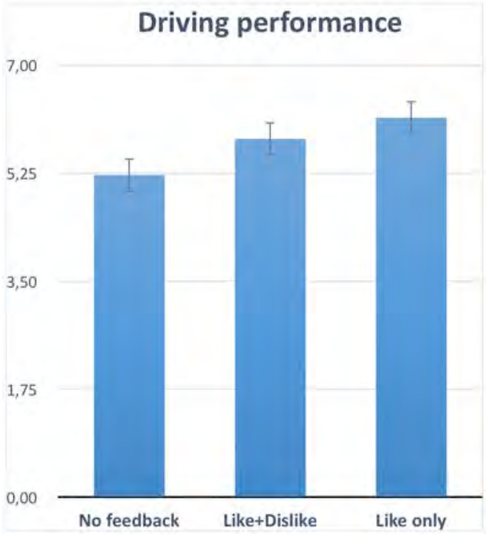

Figure 5.12 Average driving performance data generated by simulator in three conditions.

5.7.3 Concluding remarks of study 2

In this study, we investigated how drivers feel about receiving feedback to their driving behaviour from other drivers. We found only the support for hypothesis 1:

- H1. The results gave partial support for H1. The number of “Likes” and “Dislikes” showed more social driving, but there was no significant difference of objective driving behaviour data in the three conditions. In-depth interviews provided more evidence that real time feedback improved drivers’ social awareness.
- H2. According to the result of the evaluation, no difference between positive feedback and dual feedback was observed.

In study 1, sending feedback to other drivers by gesture was shown to be appreciated. In this study, improving driving behaviour by receiving feedback was supported. According to the feedback from participants, afterwards feedback, was implemented to enable drivers to reflect on their driving behaviour by reviewing videos and driving data that show why they received “Like” and “Dislike”, which led to Study 3. Furthermore, the feedback from the in-depth interviews showed that people did not reject to receiving “Dislike” and were willing to send “Dislike”. As a result, “Dislike” feature remained in Study 3.

5.8 STUDY 3: SENDING, RECEIVING “LIKES/DISLIKES” AND REVIEWING FEEDBACK AFTERWARDS

In studies 1 and 2, a system based on Driver to Driver communication employing location-based services was proposed, which enabled users to express appreciation and disapproval towards nearby drivers about their polite and impolite driving behaviour by gestures and to receive others’ evaluation through audio and visual feedback. In this study, a complete prototype was implemented to not only enable participants to send and receive feedback while driving, but also includes an interactive website for participants to review the situations in which they received and sent feedback. This prototype was used to investigate the acceptance of this system and whether it exerts positive influence on social driving behaviour.

Figure 5.13 Sending a “like”.

Besides real time feedback on the road, afterwards feedback may also be effective. Donmez et al. proposed a system for reducing driving distraction, which not only provided real time feedback, but also presented retrospective feedback at the end of a trip (Donmez, Boyle, & Lee, 2008). Their result showed that combined feedback (real time and retrospective) is more effective than only real time feedback. Roberts et al. also suggested an afterwards feedback system, which coached drivers on their performance and encouraged social conformism by comparing their performance to peers (Roberts, Ghazizadeh, & Lee, 2012). They argued that real time feedback is more obtrusive and afterwards feedback is more acceptable. There are already some applications in the market which attempt to improve driving behaviour by providing afterwards feedback. Renault car can evaluate driver's eco-driving performance and give him/her "Eco-scoring" after the journeys. Furthermore, it also provides the driver with personalised advice in line with the ratings in the report, in order to help the driver to make gradual changes towards driving more economically (Renault, 2017). *Automatic* is an adapter which can be plugged into the OBD port of a car and exports the data to user's smart phone (Porges, 2015). The user also can review his performance afterwards for improving his/her driving behaviour. As a result, afterwards feedback was adopted in the current system.

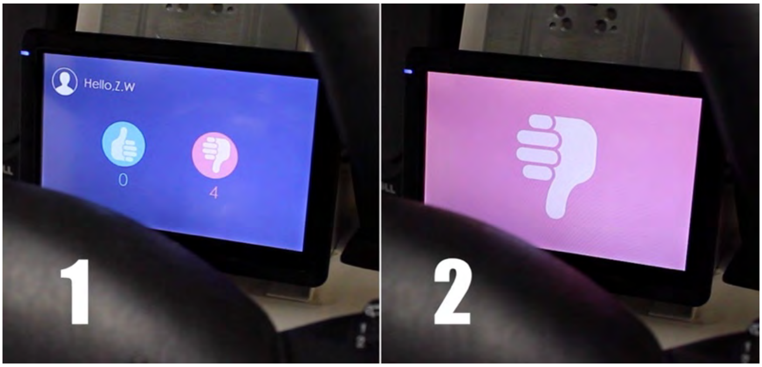

Figure 5.14 Two states of the interface of receiving real time feedback. 1. When no feedback is received, the interface shows how many "Like/Dislike" the participant already received. 2.When the participant receives a "Like/Dislike", the corresponding icon enlarges and fills the screen. At the same time, the background colour changes from deep blue (no feedback) to red (dislike) or light blue (like).

5.8.1 Design and hypotheses

Design

Sending Feedback

The flow of the “Like/Dislike” operation is the same as study 1 (Figure 5.3, Figure 5.13):

Receiving Feedback

The prototype of receiving feedback is similar as study 2, however, the interface design was improved. The interface has two states (Figure 5.14):

- State 1: The interface shows the amount of “Likes” and “Dislikes” received.
- State 2: When the driver receives a new “Like” or “Dislike”, the corresponding icon enlarges and the screen is filled with the corresponding background colour (red for “Dislike”, blue for “Likes”), which provides peripheral information, along with audio feedback. Two sound clips were selected as an auditory feedback for receiving “Likes” and “Dislikes”.

Reviewing Afterwards

An interactive website enabling participants to review the scenarios in which they received and sent “Likes/Dislikes” feedback was implemented.

The 3D interactive map was programmed in JavaScript with the library “Threejs”[1]. It enabled participants to observe the map by zooming in/out, rotating and locking their perspective on a specific target. Three layers of information were presented on the map (Figure 5.15):

1. Model layer: 3D model of the driving scenario (imported from the driving simulator), including roads, lanes, signs, important buildings etc.
2. Driving data layer: Track of driving, start point, end point, points of speeding and hard braking.

[1] http://threejs.org

3. Feedback layer: Points where they received and sent “Like/Dislike”.

A fourth layer was added, enabling Participants to “lock on” to one of the “Likes/Dislikes” icon to review a video recording (lasts from 8 seconds to 15 seconds) of the situation (Figure 5.16).

Figure 5.15 layers of information on the map: 1. Model layer, 2. Driving data layer, 3. Feedback layer

Figure 5.16 Video layer: participants could click “Like/Dislike” icon to move the perspective centre to this point. Then click the video icon to review the video record.

5.8.2 Hypotheses

We had three hypotheses:

- H1: The system has a positive influence on driving behaviour. It is predicted that the participants' driving behaviour improves according to observed driving performance (Likes/Dislikes received) and objective data of driving performance.
- H2: Afterwards reviewing exerts influence on driver's later driving behaviour. It is predicted that driving behaviour is different between drivers with afterwards feedback and drivers without afterwards feedback.
- H3: People have a positive attitude towards this concept.

5.8.3 Experiment

Equipment

The same driving simulator in study 2 was used in this study. Similar as study 2, two observers acted as "other drivers" to observe the driving behaviour and giving evaluative feedback on participants' driving behaviour. For capturing the "Likes/Dislikes" the participant sent, a LeapMotion sensor was set up in front of the steering wheel, which recognized the thumbs up/down gestures of participants and provided corresponding audio feedback.

Scenario

A highway scenario that included curves, viaducts, entrance ramps and exit ramps, along with high density of traffic was created for testing. The total duration of the scenario was 8 minutes. Seven of the other vehicles in the scenario were programmed to behave impolitely in three ways: Two vehicles drove very slowly on the overtaking lane, three changed lane suddenly and two vehicles merged in from ramps aggressively.

Participants

A between groups test involving 30 participants was conducted. The participants were divided into three groups. In order to get equal groups we balanced: driving experience, age and gender. Each group contained five male and five female participants. The average age of the first group was 26.6 (SD 3.4), the second group 25.6 (SD 2.9) and third group 27.1(SD 2.7). They had quite equal driving experience, measured in the amount of years that the participants had a driver's license: the first group was 6.7 (SD 3.4), the second group 6.8 (SD 3.2) and the third group 6.6(SD 3.3).

We recruited young people (18-35) as they are familiar with the concept of "Like" and "Dislike" from social media such as Facebook. Also, they are familiar with "new technologies" that allow connectedness between drivers. For participating the experiments, each of them they got 10 euro rewarded.

Figure 5.17 Driving simulator which integrating LeapMotion for participants to send feedback and an 8'' screen to receive feedback.

5.8.4 Observers and criteria of evaluation

Criteria of evaluation

Two observers, who were not related to this research topic, acted as "other road drivers" evaluating the participants' behaviour from a monitor. The observers were not aware of which condition the participants were allocated to. Observers gave "Like" and "Dislike" in a separate room without seeing participants' face. The standard of negative and positive evaluation was same as in the study 2.

Same as study 2, an objective assessment of the driving behaviour data was conducted, and five scores were chosen for evaluating the driving performance.

Procedure

The participants of group 1 had two driving sessions and were provided with complete feedback (both real time feedback and afterwards feedback). Group 2 had two similar driving sessions with only real time feedback. The participants of group 3 also had two similar driving session but without sending, receiving and reviewing feedback at all. The driving performance results in the second session of group 1, group 2 and group 3 were compared to verify the hypotheses (Figure 5.18).

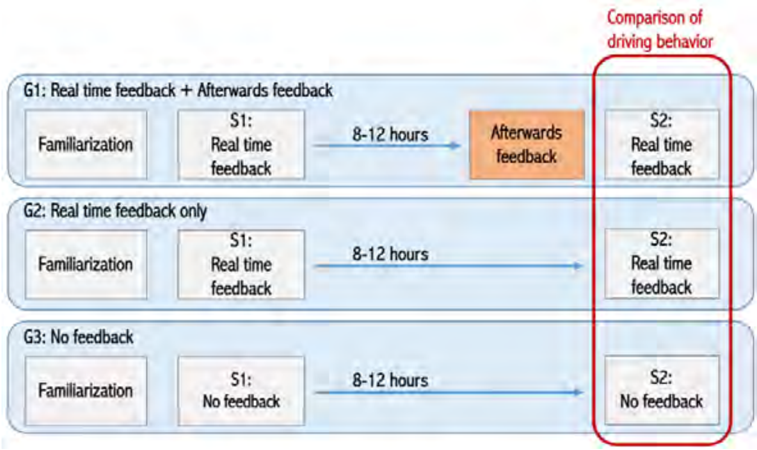

Figure 5.18 Procedure of testing between 3 groups.

Each participant was invited to drive in the simulator in a free driving mode for 30 minutes with the purpose of getting familiar to the driving simulator. Then she/he was introduced to the concept of the feedback system. Furthermore, they were asked to practice sending feedback to other cars by posting thumbs up and thumbs down in front of the LeapMotion.

The participants were then asked to assume themselves driving under this scenario:

> *You are driving to meet a client in an unfamiliar city. It's a little late. Unfortunately, you encounter heavy traffic on the highway, so drive as fast as you can until reaching the church, which is the destination of the journey. You can send "Like/Dislike" to others and may receive others' "Like/Dislike" as well.*

After that, each participant drove on the simulator for 8 minutes. The turn-by-turn navigation was disabled in this study. Participants were told to drive straight and not leave the highway.

There was an 8-12-hour interval between session 1 and session 2, allowing drivers in group 1 to log in to the website to review their driving performance after the journey and start driving again.

For the second session, all participants were asked to drive in the same scenario again. Before the second session participants in group 1 were asked to review their last driving by logging in to the website to see their performance and watching the video clips (Figure 5.16). The experimenter sat together with them and helped to explain the reasons for each "Like/Dislike" they got. There was no reviewing session for group 2.

5.8.5 Results

The driving behaviour was measured in two ways: 1) Numbers of "Likes" and "Dislikes" received and 2) Driving behaviour data as measured by the simulator.

Numbers of "Likes" and "Dislikes" received

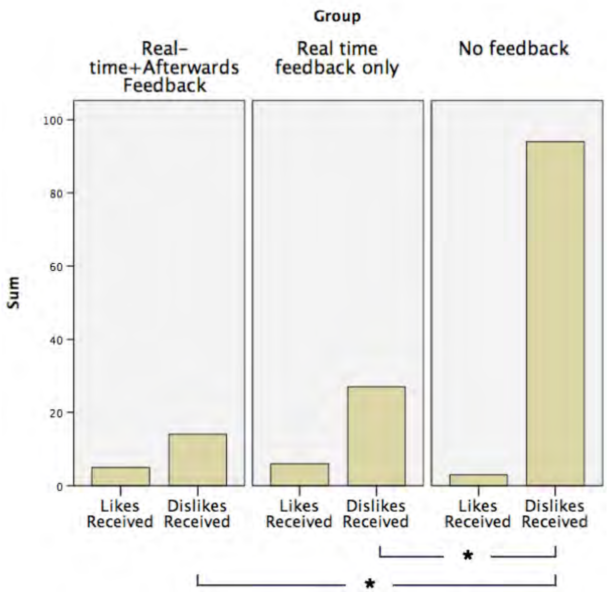

*Figure 5.19 Histogram of "Dislikes" participants received (summed across participants). * indicates significance.*

The numbers of "Likes" and "Dislikes" received in three conditions are shown in Figure 5.19. For group 1 (with real-time and afterwards feedback), 5 "Likes" (Mean per participant = 0.50, SD = 0.52) and 14 "Dislikes" (Mean = 1.40, SD = 1.17) were received in total; For group 2 (with real time feedback only), 6 "Likes" (Mean = 0.60, SD = 0.69) and 27 "Dislikes" (Mean = 2.70, SD = 2.40) in total; For group 3 (no feedback), 3 "Likes" (Mean = 0.30, SD = 0.48) and 94 "Dislikes" (Mean = 9.40, SD = 7.37) in total. Because of the low number of Likes, no statistical test was conducted on the number of "Likes". A Kruskal-Wallis test was conducted on the number of "Dislikes". Results showed that there was a significant difference (x^2 (2) = 14.011, $p = 0.001$) in "Dislikes" received between the 3 groups. Post-hoc tests were conducted applying Mann-Whitney U tests, adjusting the significance level applying Bonferroni correction. Results showed that there was a significant difference in "Dislikes" received between group 1 and 3 ($p < 0.001$, $r = 0.524$), and between group 2 and 3 ($p = 0.005$, $r = 0.245$) but no significant difference between group 1 and 2: participants in group 1 and 2 received fewer Dislikes than participants in group 3.

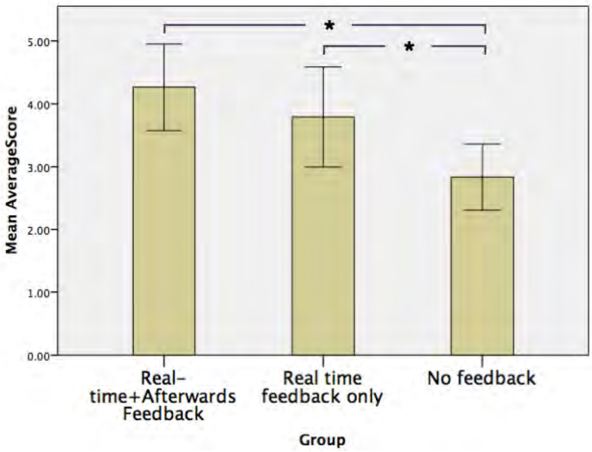

*Figure 5.20 Mean of average score of driving behaviour. * indicates significance.*

Driving behaviour data

A general score was calculated by averaging five kinds of driving quality scores generated by the driving simulator (Figure 5.20). ANOVA was conducted to compare the objective social driving performance among 3 groups. Results showed that there was a significant difference in the average score, $F(2,27) = 6.684$, $p = 0.004$. Post Hoc comparisons showed that there were significant differences between group 1 and 3 ($t(18) = 3.976$, $p = 0.001$, $r = 0.684$), and between group 2 and 3 ($t(18) = 2.494$, $p = 0.023$, $r = 0.507$), but there was no significant difference between group 1 and 2 ($p = 0.274$). The results indicate that this system significantly influenced driving behaviour, no matter there was only real time feedback or real time feedback combined with afterwards feedback. Adding the afterwards feedback on real time feedback did not significantly influence the driving behaviour. From the perspective of each item of social driving behaviour data separately, keeping safe speed ($t(18) = 2.833$, $p = 0.011$, $r = 0.555$) and Position in lane ($t(18) = 2.758$, $p = 0.013$, $r = 0.545$) were significantly different between group 1 and 3. There was no significant difference of other items.

Correlations

Spearman's rho correlation was calculated between observed performance and received "Dislikes". There was a significant negative correlation ($rho = -0.531$, $p = 0.003$) between the number of "Dislikes" participants received and the average driving performance generated by the simulator, which confirmed the consistency between the observations and the performance data: The worse they drove, the more dislikes they received. Because of the small number of Likes, no correlation was found between received "Likes" and driving behaviour data.

Comparison of the driving performance data in the warming-up session

Before this experiment, we balanced the gender, age and driving experience. After the experiment, we compared the driving performance data of the warming-up session in different groups, for checking whether they had the same basic driving performance. The mean driving performance of Group 1 is 4.39, for Group 2 is 4.03 and for Group 3 is 4.50.

Semi-structured Interviews

In order to get further feedback about this system, semi-structured interviews were conducted after the second driving session. Remarks concerned the following topics:

- Overall concept
- Real time feedback
- Afterwards feedback
- Distraction

Below we discuss the main findings per topic:

Overall Concept

In general, participants appreciated the communication between the cars, but argued that the focus should be more on communication and suggestion, (e.g. telling others that I am in hurry or apologizing) rather than judging someone's behaviour. As one participant argued: *"Like and Dislike is very binary, I would like to be able to communicate more expressively to others."* Four participants mentioned that they wanted to use "Like" for an apology to other cars when they made mistakes.

Real Time Feedback

All the participants thought that sending "Dislike" released their anger. *"I feel released after sending a 'Dislike'"*, a participant said. While analysing the amount of "Like/Dislike" that the participants gave, it appeared that they were more inclined to give 'Dislikes'. One reason for this could be that the driving situation might have resulted in more "Dislikes". As a participant said: *"There are very few reasons to give a like on the highway".*

Most participants (18 of 20) said it was not comfortable to receive "Dislikes", although none of them felt angry about the received "Dislikes". *"I know it was my fault."* one said. Regarding giving and receiving real time feedback the majority of participants said they missed the ability to be more expressive. Also from the comments about giving "Dislikes", participants would like to give more constructive feedback such as: *"Look in your back mirror"* and *"Next time pay more attention"*. More expressive feedback to give and receive would be a good addition to the system in order to have more freedom in how to communicate. Some participants mentioned occasions when they took the feedback into account: *"I slowed down when other cars would be around"* and *"I realize that I bother people"*.

Afterwards Feedback

In general, most participants in group 1 (7 of 10) were interested in the moments they received feedback. The videos were appreciated in order to get back to the context in which they had received feedback, especially when it was combined with data visualization of speeding and braking.

One participant preferred the afterwards feedback: *"It allows me to take a step back from the emotions and feelings I had while driving and allows me to look objectively to my own driving"*, while others argued that: *"I do not see any reason to look back at the offline feedback as I know what I did wrong"* and *"direct feedback is much more useful as I know at that moment I directly can learn from it, and otherwise will have forgotten what it was about"*. Two participants suggested providing an average number of "Likes/Dislikes" that people received on this road for reflection. Another interesting comment was that some participants would like to share their "Likes" on social network.

Distraction

Generally, the usability of the real-time feedback system was considered acceptable. Most participants (16 of 20) said that the interaction of giving feedback did not distract them from driving. But three participants argued that it was hard to hold the steering wheel by one hand when sending a "Like/Dislike", especially in curves. As regards receiving feedback, all participants said the message was clear especially with audio feedback: *"Audio feedback is great, I don't need to lower down my head to look at the screen"*. However, distraction came from the psychological "impact" when they received "Dislikes". Six of twenty mentioned that when they got negative feedback, they felt nervous. *"If negative feedback, give afterwards"* a participant said.

5.8.6 Discussion and conclusion

In this study, we investigated how drivers feel about receiving feedback on their driving behaviour from other drivers. The following hypotheses were examined:

- H1. The results supported H1 "The presence of this system has a positive influence on driving behaviour". Participants with feedback drove more socially than the participants without any feedback according to both observed behaviour and objective driving performance.
- H2. There was no sufficient evidence to support H2 "Afterwards reviewing exerts influence on driver's following behaviour". Adding afterwards feedback did not increase the effectiveness of the feedback compared to real-time feedback only.
- H3. Results of the semi-structured interviews supported H3 "People hold a positive attitude towards this concept", although some participants had doubts about the function of judging others' behaviour.

Generally, the system positively influenced people's driving behaviour. It enlarged the communication bandwidth between drivers by exchanging binary information. Sending "Dislike" released the anger and frustration of senders. "In the face-to-face interactions, emotional presentations serve the communicative function of calling the other person to account before their offence causes further harm or leads to physical retaliations (Parkinson, 2001. p.208)." However, when people are hidden in the steel shells, it is difficult to deliver emotional expression, then the conflicts may be quickly upgraded to physical assault. As a result, participants appreciated the sending "Dislike" feature. Sending "Like" provided a way to express appreciation. In this study, there were quite a few scenarios for the participants to use this feature, interestingly, some participants used "Like" to express apology to other drivers. It was suggested that 65 percent of "road rages" would not happen if a driver can send an apology for his unintentional (Pavelka, 1998). As a result, sending "sorry" is another feature which could be implemented in the future.

Receiving "Like" provided positive feedback for receivers and was appreciated by people. As regards receiving "Dislike", an interesting finding is that people might not feel comfortable to receive "Dislike" from others, but preferred to be able to send "Dislike", which is in line with the result of Chapter 3, where it was shown that people might not like "to receive this (negative) feedback from other drivers but would be less sensitive if they could send the message themselves" (Page 37). In any case, "Dislike" reminded the receivers that they bothered others, and it is impossible to only send "Dislike" without receiving "Dislike". "Likes" and "Dislikes" both enhance the communication between drivers and contribute to cultivating polite driving behaviour. As a result, we suggest keeping "Dislike" feature in the system.

Afterwards feedback enabled drivers to review their "Likes/Dislikes" for improving on their driving behaviour. Peer pressure such as showing average "Dislikes" people received on this road was suggested by participants.

5.8.7 Limitations and future work

This study generated rich quantitative data and qualitative information by the user test on the driving simulator, however, there are still several limitations to the research. Firstly, we balanced gender, age and driving age of participants for the between-group test. Since the base level of driving performance was not measured before the test, the different groups were not balanced with respect to base level driving performance. Therefore, we cannot completely rule out the possibility that the differences in driving performance may be caused by differences in base level performance. Secondly, participants' driving behaviour and emotional status may be biased by a simulated scenario. Thirdly, each driving session only lasted 8 minutes, therefore this study was not able to investigate participants' attitude towards this application in long term.

According to the feedback from the participants, enhancing social communication only by binary information seemed to be insufficient. In the experiments, some participants used "Like" to express "Sorry" to other drivers. As the participants suggested, there should be more expressive ways of communication rather than judging someone's behaviour. However, "Like/Dislike" only emphasises the appeal-aspect information. In the next chapter, we present the study of the concept CarNote, which in-depth enlarges the communication channel and emphasises the self-revelation side: showing contextual information such as "I am in a hurry" to other drivers.

6 Reducing Misunderstanding through Self-revelation Information[1]

Under the four sides model, we developed the “CarNote”, a concept that aims to reduce misunderstanding and conflict between drivers by revealing their self-revelation information to others. This concept was prototyped and evaluated with users in a driving simulator. The results showed that *CarNote* enhances drivers’ empathy, increases forgiveness and decreases anger to others on the road.

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[1] Based on: Wang, C., Terken, J., & Hu, J. (2017, March). CarNote: Reducing Misunderstanding between Drivers by Digital Augmentation. In Proceedings of the 22nd International Conference on Intelligent User Interfaces (pp. 85-94). ACM.

6.1 INTRODUCTION

The way people agree on how to share the road space may be understood as a form of negotiation (Rakotonirainy et al., 2014). However, the current communication methods seem insufficient for expressing the driver's intention and providing the context of their behaviour, which may lead to misunderstanding and trigger aggressive driving behaviour. The advent of everywhere available connectivity and the broad penetration of social network services provide opportunities for changing this situation (Schroeter et al., 2012), enabling social information to pass through the steel shell of cars and giving opportunities to reduce misunderstanding and strengthen empathy in order to create a more harmonious road environment.

"CarNote" emerged from the concept exploration in chapter 3, in which different "social car" ideas were discussed. The concept holds that "A driver can publish his special driving status, such as 'in a hurry to the hospital'". In the current study, this concept was elaborated, prototyped and an experiment was conducted in a driving simulator to investigate the acceptance of this application and whether it exerted a positive influence on other drivers' empathy and tolerance on the road.

6.1.1 Trigger of aggressive driving

In the last decades, the term "aggressive driving" has appeared in a large number of papers and media. It may be defined as (Ellison-Potter et al., 2001) any driving behaviour that intentionally endangers others psychologically, physically or both. Evidence both from the literature and news headlines suggests that aggression occurs among motorists on a regular basis (DCPC, 2005). A survey by the Automobile Association Britain shows that 90% of respondents reported that they had been involved in a "road rage" incident in the previous year (Joint, 1995). It was also reported by Parker et al that, over and above other variables, intentional aggressive driving behaviour makes a significant contribution to involvement in traffic accidents (Parker et al., 1995).

Understanding the causes of aggressive driving is essential for effective intervention. Therefore, a variety of explanatory models of aggressive driving have been proposed. Brewer (Brewer, 2000) provides a "conceptual framework of road rage" that links the following four factors with driver responses (aggressive driving behaviour) and outcomes (having an accident): Travel Demands, such as the time of trip; Subjective Effects, such as feelings of anonymity offered by the car; Mediating Factors, such as age and gender; and Moderating Factors, such as driver's personality and emotional state. Wright et al. (1997) proposed a model focusing on offender, victim and environmental factors. However, insufficient attention is paid in each of these models to the distinction between the interpretation of "triggering events" and the response to those events. In a report of the drugs and crime prevention committee of the state of Victoria, Australia (DCPC, 2005), a model was proposed for better understanding and efficiently intervening aggressive driving. In this model, all aggressive driving behaviour starts from the "trigger", such as being stuck behind a slow driver. Acts of violence are precipitated by the "triggering event", but more important is the interpretation of the triggers. For example, acts such as "slow driving" are not intrinsically frustrating. Rather, the frustration arises because of factors such as an individual's desire to get to his or her destination quickly and a culture that prioritizes speed on the roads over safety. Four kinds of factors, which are person-related, situational, car-related and cultural factors, influence the interpretation of "trigger".

6.1.2 Empathy and the interpretation of the "trigger event"

Empathy is an important component of social cognition that contributes to one's ability to understand and respond adaptively to other's emotions. Numerous studies have shown that there is a significant relation between empathy and forgiveness (Thompson et al., 2005) of others' mistakes.

In face to face social situations, many conflicts are alleviated by "full status information", which is highly related to empathy. Empathy requires both the ability to share the emotional experience of the other person and understanding of the other person's experience (Decety & Jackson, 2004). "The empathiser sees or hears about the situation of the empathee and imagines this situation from his own perspective" (Kouprie & Visser, 2009, p.422). In face-to-face interaction, language, tones, gestures and facial expression provide enough information to raise the empathy feeling of empathiser. For example, when a lady carrying her crying baby walks hastily to the hospital direction, we may think her baby is probably sick and give her way.

However, as regards the communication between drivers, when the design of cars depersonalizes other drivers (Haglund & Åberg, 2000) and the bandwidth of communication is limited, the reason behind the behaviour and emotional state may not be transferred easily, or even worse, it would be biasedly interpreted. Firstly, the physical distance between road users makes it difficult to obtain full information about an event. In particular, it makes it difficult to know whether an action was intentional or accidental. For example, when overtaken by another fast driver, instead of thinking of another driver as a mother on her way to take her sick child to the hospital, she may simply be thought of as a "blue Fiesta" being driven by a total waster. Secondly, the isolated nature of cars can also make it difficult to apologise for errors made while driving. Limited empathy would be generated between drivers, and as a result, the "trigger events" easily lead to aggressive reactions.

6.2 RELATED WORK

6.2.1 Mitigating misunderstanding of "trigger event" by connectivity between drivers

Many attempts have been made to mitigate the misunderstanding of "trigger events" by enhancing the communication between drivers. For example, to raise the communication quality, drivers have invented means of exchanging social cues, using headlights, hazard lamps, blinkers, and even hand gestures, in what Ellison-Potter et al. has dubbed "roadway interpersonal communication" (Ellison - Potter et al., 2001), for the purpose of transferring more social context to reduce misunderstanding on the road.

There have also been several attempts to enhance social communication with the help of physical tools. In 1990, a Belgian insurance company aimed at reducing road aggression by giving their members two plastic hands – a red "I'm sorry" hand and a green "go ahead" hand – to be used when a driving error was made (DCPC, 2005). It was discovered, however, that motorists found these mechanisms difficult to use and so the campaign ceased. At the 2001 Tokyo Motor Show (PiquetFW11, 2015), Toyota displayed a car capable of warning other drivers of the driver's mood by the colour of LED lights on the bonnet. The light display was intended to warn people how to react to approaching vehicles. However, using a physical communication method limits both the quality and quantity of information.

With everywhere available connectivity and the broad penetration of social network services, the communication between drivers on the road may change fundamentally. Firstly, quality and quantity of information can be transferred without any limitation, which may reduce the misunderstanding. Secondly, information can be delivered to a specific driver, without distracting drivers who are not concerned. Finally, staying anonymous becomes difficult, as the behaviour of road users is traced by sensors, evaluated by systems and stored in the cloud.

Figure 6.1 Lexus LF-FC concept car enables driver to send pre-set messages by gesture, such as "After you" and "Thanks", to nearby drivers (Lexus, 2015b).

This trend has drawn attention from both industry and academia. For example, Lexus unveiled the concept car LF- FC at the 2015 Tokyo Motor Show (Lexus, 2015a), which enables the driver to send a pre-set message such as "After you" to nearby drivers by gesture (Figure 6.1). Rakotonirainy et al explored the possibility of reducing driver aggression by humanizing cars and representing other drivers' eye gaze and head pose through overlaid human-like avatars (Rakotonirainy et al., 2008). An experiment in a driving simulator showed that their approach has the potential to improve social interaction between drivers, allowing clearer collective decision making between road users and reducing the incidence of antisocial behaviour in the road environment. Although some attempts to reduce aggressive driving by the latest V2V technology were proposed, so far, there is no systematic solution and related validation to address this problem under a theoretic framework.

6.3 APPLICATION

6.3.1 Aims and research hypotheses

In this study, a concept that enables the driver to receive the information of nearby cars' special driving status was proposed and a corresponding prototype was implemented in a driving simulator. Then an experiment was conducted to investigate the acceptance of this concept and whether it exerted a positive influence on empathy, forgiveness and anger between drivers.

We tested three hypotheses:

- H1: People hold a positive attitude towards this concept.
- H2: The application has positive influence on empathy and forgiveness of drivers, reducing anger.
- H3. The application does not distract from the primary driving task.

6.3.2 Concept and rationale

In the study presented in Chapter 3, 30 concepts for enhancing social communication between drivers were generated by brainstorming sessions. One of them, which was called "CarNote" and received high acceptance, is described in the following scenario:

> *Mr. Lee wants to go to the airport, unfortunately he encounters a traffic jam in the city. When he enters the highway, there is only 1 hour left before the airplane takes off. Then he puts on a virtual sign "In a hurry to airport" (The system allows each driver to use it 120 minutes per month) on the top of his car to show his situation.*

The CarNote enables drivers to convey a special driving status and emotion to others, to arouse the empathy of other drivers. Most of the psychological literature distinguishes two components of empathy (Kouprie & Visser, 2009): affective and cognitive. The affective component is "an immediate emotional response of the empathiser to the affective state of the empathee" (Kouprie & Visser, 2009, p.422). The cognitive component refers to the understanding by the observer of the other person's feeling. When another driver is "in a hurry to the airport" information is displayed on people's augmented reality windshield, providing the explanation of their fast driving behaviour, which may evoke people's memory of the same experience.

Figure 6.2 A 10" screen was fixed on the driving simulator.

The mechanism of this system only allows 2-hours usage per month for avoiding the abuse of it, which enhances the reliability of the "hurry" status, which may contribute to the empathy.

6.4 DESIGN, PROTOTYPE AND APPARATUS

6.4.1 Apparatus

A prototype based on this concept, which enables participants to know to the other drivers' emergency status was designed, developed and integrated into a driving simulator. The driving simulator included a steering wheel, seat, pedals, gears and three 32" screens (Figure 6.2).

6.4.2 Interaction design

For providing visual feedback, an enhanced navigation interface was shown on a 10" screen attached in a driving simulator. The interface which integrated 3D maps, was designed to show three layers of information (Figure 6.3):

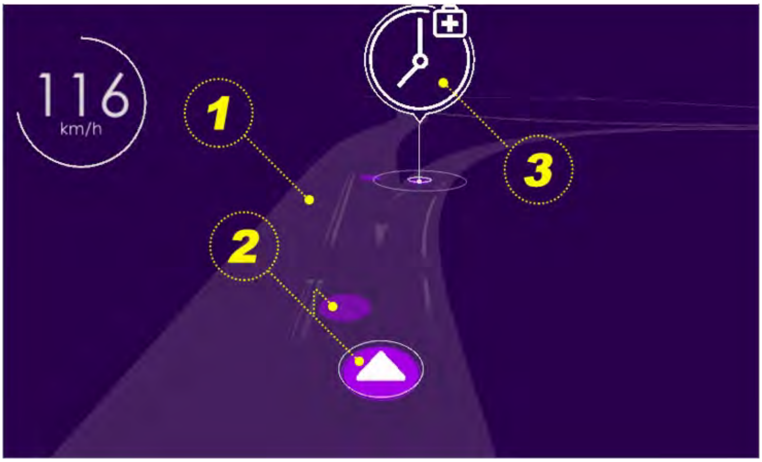


Figure 6.3 User interface design. 1) Geography layer; 2) Vehicle layer; 3) Notification layer

- 1. Geography layer: 3D model of the driving scenario (imported from the driving simulator), including roads, lanes, signs, important buildings etc.
- 2. Vehicle layer: Participant's vehicle and surrounding vehicles.
- 3. Notification layer. Information such as speed, icon of the cars with special status (Figure 6.4) and visual effect for their emergency situation.

There are two states of the interface:

- State 1: If there are no drivers in emergency status, the interface shows the own car as well as nearby cars on the road.
- State 2: If there is a nearby car in special driving status, an icon appears on top of the corresponding car interface. There are three icons applied in the scenario to show the

corresponding status: a) in a hurry to the airport. b) in a hurry to the hospital. c) searching the way now. Furthermore, an animation of ripple pops up on the car with special status to draw the drivers' attention. (Figure 6.5)

6.5 EVALUATION

6.5.1 Evaluation Setup

30 participants were involved in this experiment. The participants were divided into two groups, with Group 2 acting as a baseline condition for Empathy, Forgiveness and Anger on the road. To get equal groups we balanced: gender, driving experience and age. There were 11 males and 4 females in the first Group, 9 males and 6 females in the second Group. The average age of the first group was 24.86 (SD 2.032) and the second group 25.29 (SD 3.646). They had quite equal driving experience, measured in the number of years that the participants had a driver's license: 4.82 (SD 2.198) for the first group, 4.57 (SD 2.503) for the second group. For participating in the experiment, each of them received a 5-euro reward.

Figure 6.4 Three signs of the special status of driving: "In a hurry to the airport", "Searching the way on the road" and "In a hurry to the hospital".

6.5.2 Dependent Variables

Five questionnaires were used to evaluate the forgiveness, empathy, anger, mental effort of the application and the appeal of this application.

To measure *empathy*, the Toronto Empathy Questionnaire (TEQ) (Spreng*, McKinnon*, Mar, & Levine, 2009) was used. TEQ, which was developed by Nathan et al, is a self-report measure for the assessment of empathy. TEQ includes 20 items. To reduce the length of the entire questionnaire, the number of questions of TEQ scale was reduced to three.

To measure the *forgiveness* of the participants to impolite drivers on the road, the Heartland Forgiveness Scale (HFS) (Thompson et al., 2005) was used. HFS is a self-report measure of dispositional forgiveness, which includes three subscales: assess forgiveness of self, others, and situations. We focused on the forgiveness of other drivers; as a result, the subscale for measuring forgiveness of others, which including five questions, was used in this study.

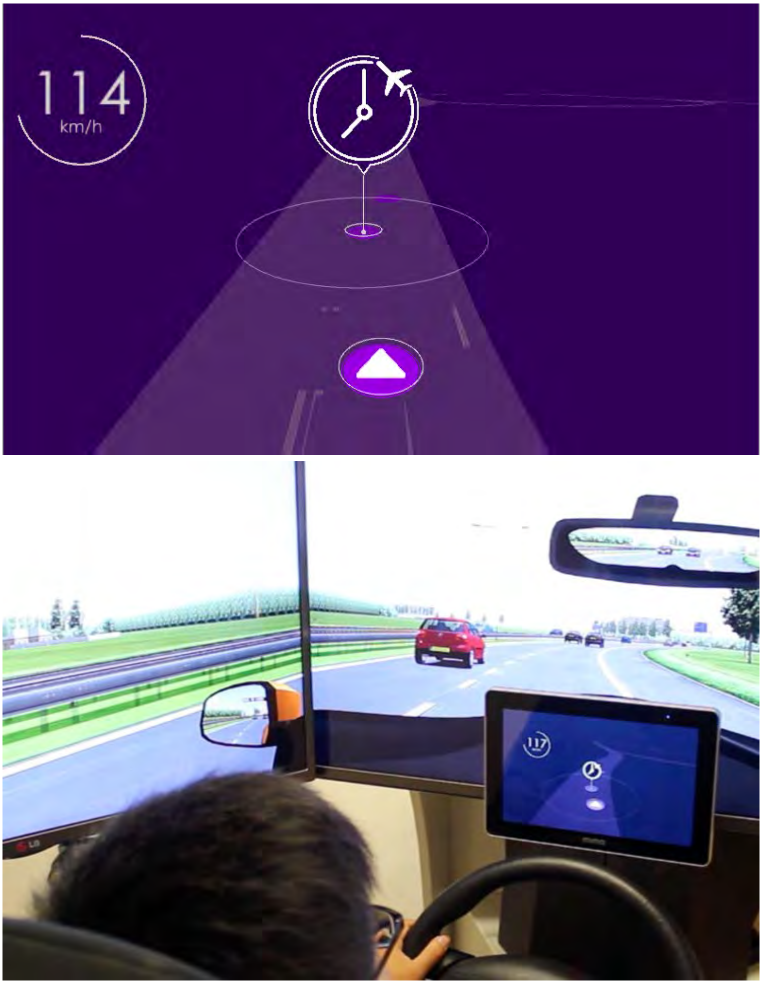


Figure 6.5 Participants matched the sign in the interface to the car in the simulated scenario.

To measure the *anger rumination* of the participants, the Anger Rumination Scale (ARS) (Sukhodolsky, Golub, & Cromwell, 2001) was used. ARS was constructed to measure the tendency to focus attention on angry moods, recall past anger experiences, and think about the causes and consequences of anger episodes. There are four components in the questionnaire, we utilized the first component "angry afterthoughts", which combines the items related to the cognitive rehearsal of recent anger episodes, and includes 6 questions. To reduce the length of the entire questionnaire, the scale was reduced to two question.

To evaluate mental effort, the Rating Scale for Mental Effort (RSME) was adopted (De Waard, 1996). RSME is a unidimensional labelled scale. Participants rate invested effort by a cross on a continuous line running from 0 to 150 mm, and every 10 mm is indicated and labelled from "absolutely no effort" to "extreme effort".

To measure the appeal of the driving situation, we used a semantic differential (Fishbein & Ajzen, 1977), which was constructed by Hassenzahl et al (Mare Hassenzahl, Platz, Burmester, & Lehner, 2000) and contains items such as "pleasant-unpleasant", "attractive-unattractive" and "desirable-undesirable" (7 point scales). Participants were asked to evaluate the feeling of their experience of the journey.

At the beginning of the questionnaire, two questions were included about whether participants noticed that there were some drivers who drove fast and pushing, or who drove slowly and hesitatingly on the road, for the purpose to investigate the reliability of the experimental manipulations. Furthermore, in the TEQ scale, HFS scale and ARS scale, each question was asked twice, one towards "fast and pushing drivers" and another towards "slow and hesitating drivers".

6.5.3 Scenario

A highway scenario that included curves, viaducts, entrance ramps and exit ramps, along with high traffic density was created for testing. The total duration of the scenario was 8 minutes. Six of the other vehicles in the scenario were programmed to behave impolitely in different segments of the road (Figure 6.6): Three drivers drove at 15% over the speed and overtook the car in front of them that drove 5% slower. Three drivers drove slowly at 60 km/h on the middle lane near merge out ramps of the highway.

6.5.4 Experiment Procedure

Before the formal test session, each participant was invited to drive in the simulator in a free driving mode for 15 minutes with the purpose of getting familiar with the driving simulator. Then each participant from group 1 was introduced to the concept of the CarNote, and asked to drive on the experiment scenario for 10 minutes and imagine that they were driving back home after work without hurry. In the experiment, two signs of “in a hurry to the airport” and one sign of “in a hurry to the hospital” appeared on the three fast and pushing cars. The sign of “searching the way now” appeared on the three slowly driving cars.

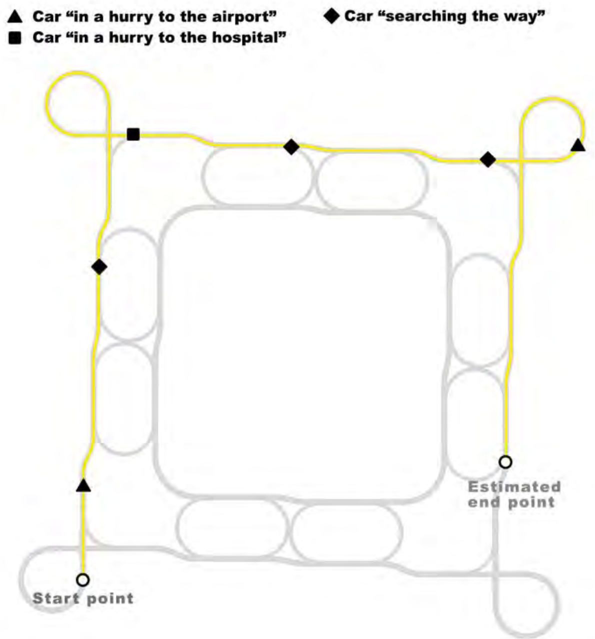


Figure 6.6 Locations where six cars appeared on the map.

For Group 2, acting as a baseline condition, there was no status sign shown but the interface of 3D maps remained. After the driving session, the participants of each group were asked to fill in the questionnaire and a semi-structured interview was conducted.

The turn-by-turn navigation was disabled in this study. All the participants were told to driving straight and not leave the highway.

6.6 RESULTS

Before analysis of the data, we checked the two questions about whether participants noticed that there were some drivers driving fast or slowly. One participant in Group 1 and one participant in Group 2 didn't notice fast drivers. As a result, these two samples were excluded from further analysis.

6.6.1 TEQ scale

An independent t-test was conducted to compare the empathy level of the two groups (Figure 6.7). Results showed that the participants in Group 1 felt significantly higher empathy to fast drivers (Mean = 3.023, SD = 0.633) than the participants in the control group (Mean = 2.453, SD = 0.549), t (26) = 2.546, p = 0.017, r = 0.447. And there is also a significant difference between empathy to slow drivers in Groups 1 (Mean = 2.834, SD = 0.700) and Group 2 (Mean = 2.332, SD = 0.488), t (26) = 2.198, p = 0.037, r = 0.396.

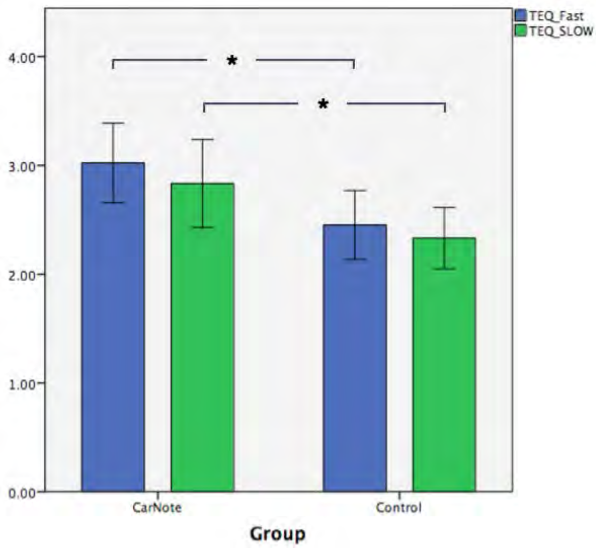


*Figure 6.7 Means and standard error of the TEQ result (ranges from 1-5). * indicates significance.*

6.6.2 HFS scale

Based on the Independent t-test, participants in Group 1 felt significantly higher forgiveness to fast drivers (Mean = 3.200, SD = 0.618) than the participants in the control group (Mean = 2.700, SD = 0.616), t (26) = 2.144, p = 0.042, r = 0.388. And there is also a significant difference between forgiveness to slow drivers in Groups 1 (Mean = 2.957, SD = 0.666) and Group 2 (Mean = 2.286, SD = 0.739), t (26) = 2.525, p = 0.018, r = 0.444. (Figure 6.8).

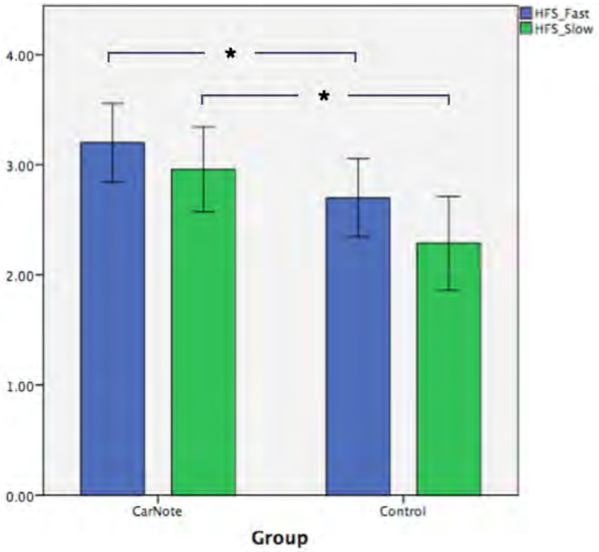


*Figure 6.8 Means and standard error of the HFS result (ranges from 1-5). * indicates significance.*

6.6.3 ARS

Based on the Independent t-test results, there are no significant differences of Anger Rumination between participants in the two groups, neither to fast driver nor to slow drivers, although the Mean of Group 1 is lower than Group 2, both for faster drivers (Group 1: Mean = 3.071, SD = 1.071; Group 2: Mean = 2.929, SD = 0.917; t (26) = 0.379, p = 0.708) and slow drivers (Group 1: Mean = 3.191, SD = 0.694; Group 2: Mean = 2.964, SD = 1.046; t (26) = 0.675, p = 0.506) (Figure 6.9).

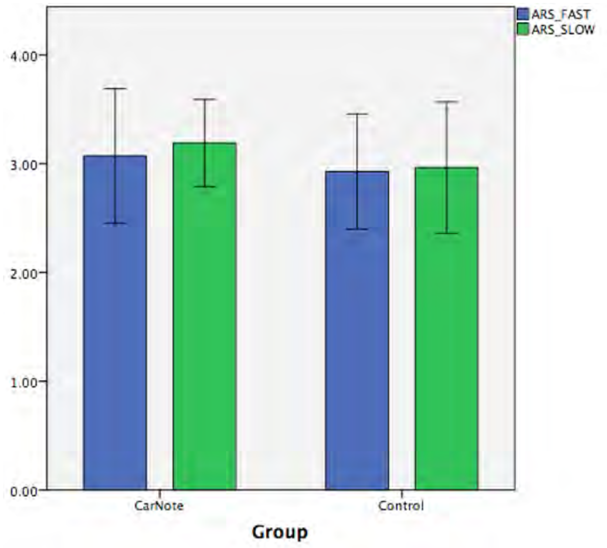


Figure 6.9 Means and standard error of the ARS result (ranges from 1-5).

6.6.4 Mental effort

Regarding the mental effort of participants, which is measured by the RSME scale, there is no significant different between the two groups based on the Independent T-test: $t(26) = 1.300$, $p = 0.205$. The mean mental effort of the group where participants could see signs was 43.714 with a SD of 20.823, compared with the control group whose mean was 34.214 with a SD of 17.730. (Figure 6.10).

6.6.5 Appeal

This questionnaire provides insight into the appeal of this journey. Based on the Mann-Whitney U Test, there is no significant difference between the result of the two groups ($U = 59.50$, $z = -1.777$, $p = 0.077$, $r = -0.336$). But the M*dn* of Group 1 (M*dn* = 5.74) is higher than Group 2 (M*dn* = 4.96) (Figure 6.11).

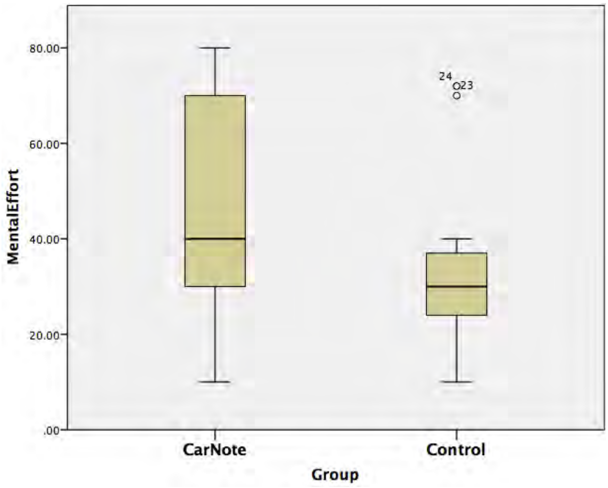


Figure 6.10 Means and standard error of the RSME result (ranges from 0-120).

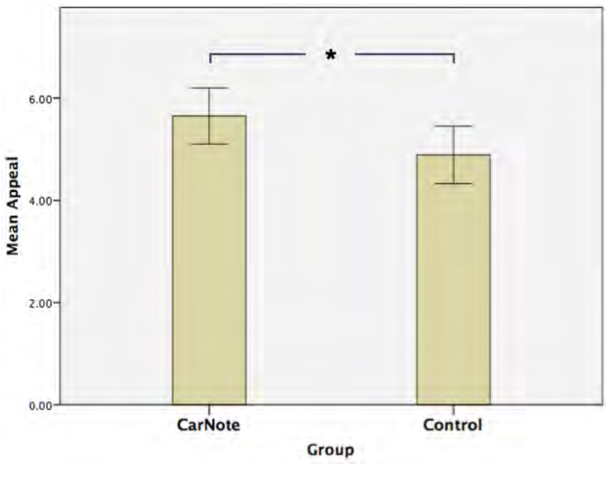


*Figure 6.11 Means and standard error of the Appeal questionnaire (ranges from 1-7). * indicates significance.*

6.7 QUALITATIVE RESEARCH

In order to gain structured insights from our study, we transcribed and analysed the interview data by qualitative content analysis (Hsieh & Shannon, 2005). In this section, we report on the results of in total 121 textual descriptions. The descriptions were coded by the first author using the following three themes: 1) Factors influencing the acceptance of the concept, 2) Factors influencing the empathy and tolerance and 3) Factors influencing the distraction on driving behaviour.

Table 6.1 Categorization of textual descriptions with the numbers of quotes and participants for each (sub-)category indicated in the parentheses.

Category (N of quotes/participants)	Sub-Category (N of quotes/participants)	Exemplar quotes
Theme 1: Acceptance: Which factors influence the people's attitude of the concept?		
General Description (16/14)	Positive (14/12)	*"I think it's really innovative, I could fully accept this idea."*
	Negative (2/2)	*"I don't really care why they are rushing."*
Positive Factors (11/5)	Reducing Anger and misunderstanding (3/3)	*"I may feel better if there is a badge. It feels like that he said 'sorry' to you."*
	Safety (3/2)	*"When I know that he is in a hurry...I don't want to be involved in their driving, I just let them go."*
	Efficiency (2/1)	*"If you can know he is rushing to the airport, you can give him the way, he doesn't need to warry about changing lane consistently."*
	Limitation (3/3)	*"Limitation is absolutely necessary, otherwise people will misuse this idea."*
Negative Factors (6/3)	Inducing aggressive driving (4/1)	*"...he is already fast, exposing that he is going to the airport may make him even more aggressive."*
	Reliability (1/1)	*"But I doubt that he just wants to drive fast."*

	Distraction (1/1)	*"...as long as you are not distracted."*

Theme 2: Which factors influence the empathy and tolerance?

Drivers in a hurry (24/14)	Feeling Empathy (16/12)	*"Because I am used to be in a hurry to the airport, I can understand him"*
	No Empathy (8/2)	*"Although you are in hurry, you cannot drive over the speed limitation, right?"*
Searching-way drivers (21/14)	Feeling Empathy (9/7)	"I wouldn't say exactly related... The movie interest maybe too small to ...really think of ...relation."
	No Empathy (7/7)	*"...highway is not a difficult map...of course, there are some exits...but you know where to go in the global picture."*

Theme 3: Which factors influence the distraction on driving task?

General judgment (16/14)	No distraction (11/9)	*"You have to use the GPS anyway. When you look at the map and speed, you will see the information too."*
	Certain distraction (5/5)	*"Sometimes I felt a little distraction."*
Mapping (12/10)	Not difficult (8/7)	*"You have to see the navigation panel when you are driving. It is just like one more car is popping up in the map, we can consider like that."*
	Difficult (4/3)	*"A little difficult, especially when there were several cars in front of me, I didn't know which car it was."*
Information (15/6)	Icons (7/5)	*"The icon is well designed, very clear."*

Difficulty of seeing information of the behind car (5/2)	*"It doesn't show the car behind you, only show the car ahead.*
Kinds of signs (2/1)	*"It could be more direct just like an indicator. Maybe just fast and slow sign is enough, then I know he has some issue…I don't need to know the reason."*
Auditory feedback (1/1)	*"You can often hear the ambulance approaching and you move quickly in advance… from some distance, if I know the car approaching which is in a hurry, I can make the way in advance for him."*

6.7.1 Acceptance

33 quotes in this theme provide insight on people's general idea of this application. Participants were firstly asked to "describe this application", then to explain the reason of the descriptions. Three dominant categories were generated from the analysis of the quotes: *general description, positive factors* and *negative factors*.

Figure 6.12 Words cloud of users' description of CarNote.

Description

Sixteen quotes from fourteen participants showed people's general impression of this application. Almost all the quotes (14 from 12 participants) were positively worded, which indicated that this application got very high acceptance by people. The most used words by participants are "like" (three quotes), "good" (two quotes) and "useful" (two quotes) (Figure 6.12).

> *"I think it's really innovative, I could fully accept this idea."*

Positive factors

Eleven quotes from five participants revealed factors that positively influenced people's attitude towards this application. Three quotes from three participants mentioned that the CarNote enhanced safety because it enabled them to know "the purpose of other people". Three quotes from two participants said it would reduce their misunderstanding on the road if they knew the reason for others' behaviour. One participants stated that they can benefit from this application if they were also in an emergency. Three participants reiterated the necessity of the limitation mechanism for avoiding abuse of this feature.

> *"When I know that he is in a hurry…I don't want to be involved in their driving, I just let them go."*

> *"I may feel better if there is a sign, it feels like he said 'sorry' to you."*

Negative factors

Six quotes from three participants mentioned negative factors that influenced their acceptance of this application. Four quotes mentioned that this application may "induce" more aggressive driving behaviour. Another concern of participants is the distraction, which was mentioned by four participants. One participant said he thought this concept would "increase safety, as long as you are not distracted."

> *"…he is already fast, exposing that he is going to the airport may make him even more aggressive."*

6.7.2 Empathy and tolerance

This theme collected 45 quotes describing whether participants could feel empathy for others as well as the reason behind it. Most participants (twelve of 14) confirmed that they could understand and be tolerant of the abnormal behaviour of the cars with virtual signs, however, the attitude towards fast drivers are quite distinct, which was in line with the quantitative data.

Drivers in a hurry

Twelve participants stated that they could understand the drivers who are in a hurry (both hurry to the airport and hospital). Five participants said that they would give way to them. Five quotes from four participants mentioned that they could understand people who were in a hurry because they have experienced the same situation before. Three participants showed especially compassion if others were going to the hospital.

> *"Because I am used to be in a hurry to the airport, I can understand him"*
>
> *"… especially in a hurry to the hospital, I am sure that I will give him the way."*

Searching-way drivers

In contrast, only seven participants said that they were tolerant of slow drivers on the road. The remaining seven participants stated dissatisfaction on slow drivers. Four of them said that searching the way on the highway "is not convincing" as the roads on the highway were not complicated.

> *"...highway is not a difficult map…of course, there are some exits…but you know where to go in the global picture."*
>
> *"Slow drivers are much more annoying than fast drivers…someone driving aggressively, he has to pay attention; but someone driving slowly, we have to pay attention."*

6.7.3 Distraction

Forty-three quotes in this theme described the participants' opinion of driving distraction caused by CarNote. Three dominant categories emerged from the analysis: *general judgment, mapping and information.* Each category contained positive and negative descriptions about the distraction by CarNote.

General judgment

Sixteen quotes from fourteen participants described the general opinion of distraction. Nine participants thought CarNote did not distract from their driving task. Five participants confirmed that they felt a little distraction.

> *"No (distraction), not really. In my case, I could feel like using my navigation system. It's quite easy to get the information."*

> *"You have to use the GPS anyway. When you look at the map and speed, you will see the information too."*

Mapping

Twelve quotes from ten participants mentioned matching the signs in the interface to the cars in the simulated scenario. Most of the participants (seven of ten) did not have difficulty in mapping the dots and icon on the screen to the cars outside. As in daily life, they get used to mapping the roads, intersection and buildings of the navigation to the real world outside the windshields. However, three participants said that they had to pay a little effort on mapping; a head-up display and augmented reality display were suggested by two participants.

> *"A little difficult, especially when there were several cars in front of me, I didn't know which car it was."*

> *"You have to see the navigation panel when you are driving. It is just like one more car is popping up in the map, we can consider like that."*

Information

Fifteen quotes from six participants were about the content and quality of information they got. Seven quotes from five participants stated that the icons were easy to recognize and understand. But one participant said that the size of the icons was “too small” for glancing while driving and sometimes he “ignored” them.

> *“The icon is well designed, very clear.”*

One participant thought showing the specific reason of hurry status was unnecessary. She suggested that only two signs were enough: “In a hurry” and “have to drive slow”.

> *“It could be more direct just like an indicator. Maybe just fast and slow sign is enough, then I know he has some issue…I don’t need to know the reason.”*

The “ripple” animation provides warning information that there is a car with a special status behind you. However, two participants suggested that more information of the following car could be displayed so that they can “make way for these cars”. Furthermore, audio feedback was also recommended by one participant.

> *“You can often hear the ambulance approaching and you move quickly in advance… from some distance, if I know the car approaching which is in a hurry, I can make the way in advance for him.”*

6.8 CONCLUSION AND DISCUSSION

In this study, we investigated how drivers feel about showing surrounding drivers’ special status. The following hypotheses were examined:

- H1: “People hold a positive attitude towards this concept.” There was no significant difference according to the Appeal questionnaire. However, according to the results of the interviews, most participants were interested in this concept.
- H2: “The application has a positive influence on empathy and forgiveness of drivers, reducing anger rumination.” The result of the questionnaires and qualitative research partly supported H2: There is significant difference of TEQ and HFS scales, but no significant difference of ARS scale between two groups. Furthermore, the results show that participants’

attitude towards fast drivers and slow drivers are highly distinct.

- H3. “The application does not distract from the primary driving task.” The application exerted certain influences on normal driving task. According to the RSME scale, there were no significant differences between the result of two groups. However, based on the analysis of qualitative data of in-depth interview, one-third of all the participants felt a certain amount of distraction.

The questionnaires and qualitative research showed that CarNote enhanced drivers’ empathy to fast and less to slow drivers. However, participants held very different attitude towards aggressive drivers and slow drivers. According to the in-depth interview, half of all the participants could not understand slow driver’s behaviour, which was in line with the result of HFS scale. Participants stated that CarNote evoked their imaginative apprehension of another’s emotional state and recalled the memory of the same situation they experienced before. But for the drivers who were searching ways on the highway, it was not reasonable and even more dangerous compared with aggressive drivers. Therefore, they could understand the driver’s hurry status as they experienced the same situation but had less empathy for slow drivers.

As mentioned above, empathy consists of affective and cognitive components, which were described by Decety et al. (Decety & Jackson, 2004) as “feeling what another person is feeling” and “knowing what another person is knowing”. In this study, the cognitive component was mainly used to induce empathy of others’ situation, which is concerned with intellectually taking the perspective of another person. In contrast, the affective component is an immediate response to the empathee, such as responding with a smile when somebody smiles at you (Gladstein, 1983). In the in-depth interview session, one participant mentioned that the virtual signs provided the feeling of apology from others, which reduced her anger of their impolite driving behaviour. If a hurried driver’s sign contains emotional information (e.g. apologetic emoji), he may immediately receive emotional compassion by some people around him.

The result of the AFS scale did not show significant differences between the anger rumination of two groups. It may be that because of the experiment environment, participants were hard to be aroused in angry emotion.

Distraction was reported by one-third of the participants and according to the result of the RSME scale, the mean of mental effort of the group with CarNote was higher than the control group, although no statistically significant difference was found. This result indicated that distraction was inevitable when using CarNote. As suggested by some participants, novel HCI technology has the potential to solve this problem, such as augmented reality.

6.9 LIMITATIONS AND FUTURE WORKS.

This study yielded rich quantitative data and vivid qualitative information by the user test on the driving simulator. However, there are many limitations to the research. Firstly, in this study, we balanced gender, age and driving age of participants for the between-group test. However, the participants' driving behaviour, empathy and forgiveness were not balanced, which may influence comparison of the data in two groups. Secondly, participants' driving behaviour and emotional status may be biased by the limitations of the driving simulator. The performance of manoeuvring the vehicle may be different in the real world. Moreover, "others" who were in a hurry or searching the way may have been seen as a computer agent rather than a real person, which makes the simulated scenarios different from a real social situation. Fourthly, each driving session only lasted 10 minutes, therefore this study was not able to investigate participants' attitude towards this application in long term. Fifthly, there was lack of objective data evaluation. In this study, subjective questionnaires and qualitative content analysis were adopted for investigation. However, several objective data such as bio-signal (heart rate variability, skin conductance etc.), gaze tracking and facial expression recognition and driving behaviour data (acceleration, speed and brake etc.) could also be used to evaluate participants' feedback of this application.

In this study, we utilized a novel application, CarNote, as a probe to explore the possibility of enhancing communication by connectivity technology in the future. Generally, CarNote got highly acceptance by participants. In one hand, it increases the transparency on the road and reduces misunderstanding between drivers. In another hand, CarNote could also be seen as a protocol to optimize the road infrastructure sharing. The social computing and everywhere available connectivity change the way we cooperate and share resources, such as Uber[1] or Airbnb[2]. It would also change the way we share the road. For example, the system could distribute the permission of driving downtown in rush hour according to driver's usage of road.

In Chapter 5, it is suggested that two aspects of the car-related factor that play a part in causing aggressive driving are mostly mentioned in previous research: *communication difficulties* and *anonymity* on the road. The applications Like/dislike and CarNote enlarge the communication channel between drivers to improve driving behaviour and experience. However, they do not decrease the anonymity among drivers. Although privacy is an issue in the context of driving (Donmez et al., 2008), there is some space of "social transparency" (Stuart, Dabbish, Kiesler, Kinnaird, & Kang, 2012) such as showing that the front driver is an elderly person or even a "Stars War" fan, which could also influence people's attitude toward others. This will be taken up in the following chapter.

[1] www.uber.com

[2] www.airbnb.com

7 Enhancing Social Closeness between Drivers by Revealing Relationship Information

Under the Four-Sides model, the concept *iSticker* and *MusicHound*, two concepts that involve revealing the social relationship between drivers were developed into prototypes and evaluated on a driving simulator. The results show that *iSticker* and *MusicHound* may enhance drivers' social closeness and belongingness, and increase the appeal of journey.

7.1 INTRODUCTION

Humans are social by nature. The pursuit of relatedness is one of the three basic motivating principles which underlie social behaviour (Baumeister & Leary, 1995). One cannot live for a long time without socialising with others. Social networks such as Facebook fulfil the need of belongingness of people (Seidman, 2013) and mobile internet services enable us to get used to staying in touch anywhere anytime. However, from the social perspective, the car is an isolated space. While driving, people are "encapsulated in a domestic, cocooned, moving capsule, an iron bubble" (Urry, 2007). The car offers a confined space, which allows for individuality and privacy in a public space. However, it detaches drivers from their environment at the same time. This kind of detachment decreases drivers' belongingness and closeness to other drivers, which may lead to loneliness in a long journey and selfish driving behaviour. The advent of everywhere available connectivity and the broad penetration of social network services offer opportunities for changing this situation (Schroeter et al., 2012).

In chapter 3, thirty different "social car" ideas were discussed with more than twenty people. In the studies reported below, *iSticker* and *MusicHound* emerged as two promising concepts. The concepts were elaborated, prototyped and experiments were conducted in a driving simulator to investigate the acceptance of the applications and whether it exerted a positive influence on driving experience and social closeness on the road.

7.2 RELATED WORK

7.2.1 Mix without meet: lack of closeness between drivers

Social closeness is defined as "the experience of positive emotions toward another individual or set of individuals" (R. R. Ratan & Tsai, 2014). While driving, a driver usually encounters tens or hundreds of other drivers on the road. However, the bandwidth of interaction is restricted to signals of cars such as horn, indicator or using the clunky movement of the vehicles as a form of body language (Juhlin, 2013). Drivers are constrained behind their steering wheels and "interact" monotonously with non-human-like machines on the road. Although people "meet" many drivers on the road, perceiving no social bonding or relationship between them will hinder the closeness between drivers (Baumeister & Leary, 1995). Lack of social closeness leads to aggressive driving behaviour and less belongingness during of the journey (Baumeister & Leary, 1995; R. R. Ratan & Tsai, 2014).

7.2.2 *Lack of closeness between drivers contributes to aggressive driving behaviour.*

In the *CSCW (computer-supported cooperative work)* domain, social closeness is an important factor that influences the collaborative willingness (Reychav, Ndicu, & Wu, 2016), task effort (Walther, 1997) and outcome (Walther & Bunz, 2005) of the online cooperation. Sharing the road is a form of cooperation (Juhlin, 2013; Renner & Johansson, 2006). As a result, social closeness between drivers also exerts influence on the drivers' coordination with each other.

A field study by Ellison et al. (1995) found that drivers behave more aggressively to drivers who use tinted windows. Based on a survey and interview study, Ratan et al. (2014) supported there is a negative correlation between the social closeness and driving aggression. They suggested that when drivers feel socially closer to others, they may "drive in ways that are more considerate of others' safety". Research by Caspi et al. (1997) and Gulliver et al. (2007) suggested that social closeness is a factor that contributes to risky driving behaviour between young adults. A simulation study conducted by Mitrevska et al. (2012) found that establishing social bonding through revealing common personal interests between two drivers reduces their aggressive behaviour to each other.

This can be explained by the relation between the social closeness and positive empathy (Morelli, Lieberman, & Zaki, 2015), tolerance (Brosnan, Schiff, & De Waal, 2005) and trust (Podobnik, Striga, Jandras, & Lovrek, 2012). This means when a driver feels closer to another one, he is more willing to understand the driver's experience (empathy), shows more forgiveness of others' mistake (tolerance) and believes in reciprocity (trust).

7.2.3 *Lack of closeness between drivers leads to social disconnection.*

Being related to others is one of the basic human needs (Baumeister & Leary, 1995; Rettie, 2003). However, being constrained behind their steering wheels and "interacting" monotonously with non-human-like machines on the road detaches drivers from their environment and social society, which may lead to loneliness and decrease the pleasure of the journey. According to an interview by Redshaw et al. (2012), some drivers who commute on the same route every day complain about the boredom of spending time on such journey and describe it as a compulsory task. Nowadays, this phenomenon becomes more obvious while we are getting used to “stay always online” using our mobile devices. Therefore, while our bodies are physically constrained in the vehicle, our minds are trying to escape from the “iron cage” and regain the connection with the outside world. People take dangerous action such as calling or texting their friends even though they know this activity may lead to severe distraction on their driving task. A government survey in 2011 (Petroulias, 2009) showed that, despite legislative bans, 59% of Australian drivers used their mobile, with 31% sending text messages while driving.

7.2.4 Increasing social closeness by digital augmentation

Previous research suggests that the similarity between people is related with closeness (Tesser & Campbell, 1980; Tesser & Paulhus, 1983). Liviatan et al. (2008) argued that interpersonal similarity can be seen as a dimension of social closeness, based on the experiment result which shows that similarity influences one’s judgment of others’ actions. In the driving scenario, the only clue which reveals the identity of drivers is the appearance of the vehicle. We feel little inclusion as few similarities can be found based on the styling and brand of others’ vehicles.

With everywhere available connectivity and the broad penetration of social network services, the communication between drivers on the road may change fundamentally. Firstly, quality and quantity of information can be transferred without any limitation, and rich content such as image, voice or text can be sent by digital channels. Secondly, information can be delivered to a specific driver, without being released to irrelevant drivers. As a result, based on analysis of participants’ social media profile, such as Facebook, it is possible to establish social bonding between drivers by exposing their similarity to each other. Some attempts have already made to enhance the social closeness in this way.

Motorcycling is a strikingly social activity, and motorcyclists are also explicit about their interest in other motorcyclists, which is visible in the way they often greet other bikers they meet along the road. Esbjörnsson et al. (2003) implemented a prototype called "*Hocman*" which enhances brief traffic encounters between bikers by playing a sound clip and automatically exchanging personal HTML pages. Field study results showed that bikers enjoyed such added value to biking.

Yasar et al. (2010) proposed a system which could exchange traffic information, such as congestion or free parking place between drivers. By combining social network and vehicular network, the system enabled such information to be transferred by "a friend-of-a-friend". This social bonding that increases the closeness between strange drivers makes the information more trust-worthy.

Schroeter et al. (2012) proposed a concept of *Visualising Degrees of Separation*, which would "humanise" cars. By analysing the drivers' social network, the degree of separation and avatar of others could be displayed in the augmented-reality windshield, for the purpose of evoking people's "emotional" response and to decrease anti-social driving behaviour. However, there is no further development of this concept, simulator nor field study.

Mitrevska et al. (2012) suggested a system which established bonding between drivers by matching the similarity of their Facebook profile to reduce anonymity. Then this concept was prototyped into a simplified simulation game where the participants could not drive but could press four buttons (AngryComments, HornHonk, HappyFace or ThumbsUp) to other drivers. The user test showed that participants behaved more politely to the drivers who had common personal information.

So far, most of the studies are limited to concept exploration, questionnaire survey or empirical study, and there is no systematic research conducted to investigate on how digital information influences social closeness. This study tried to establish social bonding between people by matching drivers' profiles, to increase social closeness between proximate drivers on the road.

7.3 APPLICATION

7.3.1 Aims and research hypotheses

Two concepts chosen from Chapter 2, which enable the driver to see a virtual sticker and hear the music of nearby cars, were proposed and corresponding prototypes were implemented in a driving simulator. Then two user tests were conducted to investigate the acceptance of these concepts and whether they exerted a positive influence on social closeness and belongingness.

We tested four hypotheses:

- H1: People hold a positive attitude towards the two concepts.
- H2: The applications have a positive influence on social closeness.
- H3: The presence of interaction between drivers will contribute to the belongingness.
- H4. The applications do not distract from the primary driving task.

In the following sections, the two studies are presented. The outcomes will be discussed jointly in section 7.6.

7.4 STUDY ONE: ISTICKER

7.4.1 Concepts and rationale

iSticker: extending the bumper sticker culture to the digital world

Bumper stickers and other signs affixed to the vehicles are a ubiquitous culture in the U.S. Generally, there are two psychological motivations of the usage of bumper stickers, as proposed by previous research: showing differences and showing affiliated (Endersby & Towle, 1996). According to an empirical survey by Case, people use the bumper to express their individuality (Case, 1992). Based on the result of investigation of bumpers stickers that communicated candidate preferences during the 1992 presidential election, Endersby et al. (1996) suggested that: “display of bumper stickers often is an expression, not of individualism, but of group affiliation”, and drivers want to use their vehicle as a “form of identification and solidarity with a group sharing common beliefs”.

However, traditional ways, such as physical bumper stickers, ornamentations or “objects” inside windshields restrict the communication between members of the same community.

iSticker, which is an extension of the bumper sticker in the digital world, has the potential to enhance the social connectedness between drivers. It is described in the following scenario:

> *Peter is a Marvel hero fan. Yesterday he chose the virtual icons “Spiderman” in the “iSticker” online service for his car. Now he is on the highway to Berlin. On the road, he sees several fellow drivers who are have “Ironman”, “Deadpool” and “Ant-man” badges when they approach. He knows that they can see his as well because they chose the icons in same category.*

iSticker enables drivers to choose a virtual sticker, such as movie characters, football teams or cartoon figures. It matches anonymous drivers on the road, as the drivers who have similar interests can see each other’s stickers.

Figure 7.1. A 10" screen was integrated in the driving simulator.

7.4.2 Apparatus

A prototype based on the concept, which enables participants to see to the other drivers’ “stickers” was designed, developed and integrated in a driving simulator. The driving simulator included a steering wheel, seat, pedals, gears and three 32” screens (Figure 7.1).

7.4.3 Design and prototype

For providing visual feedback, an enhanced navigation interface was shown on a 10" screen attached in a driving simulator. The interface which integrated 3D maps, was designed to show three layers of information (Figure 7.2):

Figure 7.2 User interface design. 1) Geography layer; 2) Vehicle layer; 3) Notification layer

1. Geography layer: 3D model of the driving scenario (imported from the driving simulator), including roads, lanes, signs, important buildings etc.
2. Vehicle layer: Participant’s vehicle and surrounding vehicles.
3. Notification layer. Information such as speed, virtual “stickers” of other cars and participants’ cars.

There are two states of the interface:

- State 1: If there are no drivers with “Stickers” in the same community, the interface shows the own car as well as nearby cars on the road.
- State 2: If there is a nearby car with a “Sticker”, an icon appears on top of the corresponding car interface.

Furthermore, an animation of ripple pops up on the car with the sticker to draw the driver's attention. (Figure 7.3)

7.4.4 *Evaluation*

Evaluation Setup

40 participants were involved in this experiment. The participants were divided into two groups, with Group 2 acting as a baseline condition for Connectedness and Social inclusion on the road. In order to get equal groups we balanced: gender and driving age. There were 15 males and 5 females in the first Group, 15 males and 5 females in the second Group. They had quite equal driving experience, measured in the amount of years that the participants had a driver's license: 5.95 (SD 2.72) for the "Sticker" group 5.50 (SD 3.53) for the control group. For participating in the experiment, each of them received a 5-euro reward.

Figure 7.3 The virtual sticker in the interface matches the car in the simulated scenario.

Choosing “iStickers”

Before the test, each participant was asked to select one virtual “Sticker” to put on their car from a list (Figure 7.4). The list contained 119 “Stickers” in eleven categories, which included avatar figures from movies, TV play, cartoons, games and football teams. Each category contained at least four “Stickers”.

Dependent variables

Four questionnaires were used to evaluate the belongingness, social closeness between participants and other drivers, mental effort of the application and the appeal of this application.

To measure belongingness, the *Revised Social Connectedness Scale* (SCS-R) (Lee, Draper, & Lee, 2001) was used. SCS-R was developed by Lee et al., to measure belongingness based on H.Kohut’s self-psychology theory (Baker & Baker, 1987). SCS-R includes 20 items. To reduce the length of the entire questionnaire, the number of questions of the SCS-R scale was reduced to 6, including three positively worded and three negatively worded ones.

To measure the social closeness between the participants and surrounding drivers on the road, the pictorial Inclusion of *Community in Self* (ICS) scale was used (Mashek, Cannaday, & Tangney, 2007). The scale is composed of 6 pictorial representations of two circles (one representing the community and the other representing the self). Each of the pictorial representations varies from its neighbour by increasing the intersection surface. An increase in this intersection shows a closer sense of inclusion to the community. In the questionnaire, the community side was described as all the other drivers.

To evaluate mental effort, the *Rating Scale for Mental Effort* (RSME) was adopted (De Waard, 1996). RSME is a unidimensional labelled scale. Participants rate invested effort by a cross on a continuous line running from 0 to 150 mm, and every 10 mm is indicated and labelled from “absolutely no effort” to “extreme effort”.

To measure the appeal of the driving situation, we used a semantic differential (Fishbein & Ajzen, 1977), which was constructed by Hassenzahl et al (Mare Hassenzahl et al., 2000) and contains items such as “pleasant-unpleasant”, “attractive-unattractive” and “desirable-undesirable” (7 point scales). Participants were asked to evaluate the feeling of their experience of the journey.

Figure 7.4 Some virtual stickers which could be chosen by participants. The stickers were designed by Konrad Kirpluk (Kirpluk, 2014) and the usage for experiments were authorised.

At last, a Likert scale about how participants liked the other cars’ “Stickers” appearing in the scenario was also included, for the purpose of examining whether they like the others’ icons.

Scenario

A highway scenario that included curves, viaducts, entrance ramps and exit ramps, along with low density of traffic was created for testing. The total duration of the scenario was 10 minutes. The turn-by-turn navigation was disabled in this study. Participants were told to driving straight and not leave the highway.

Experiment Procedure

Before the formal test session, each participant was invited to drive in the simulator in a free driving mode for 10 minutes with the purpose of getting familiar with the driving simulator. Then each participant from the "Sticker" group was introduced to the concept.

For each participant in the "Sticker" group, there were three cars, each with a different "Sticker" from the same category appearing in three different segments of the road. For the other group, acting as a baseline condition, there was no car with a "Sticker" but the interface of 3D maps remained. After the driving session, the participants of each group were asked to fill in the questionnaire and people in group 1 had a semi-structured interview.

7.4.5 Results

SCS-R scale

An independent T-test was conducted to compare the social connectedness level of the two groups. Results showed that the participants who could see others' "stickers" felt significantly higher belongingness (Mean = 3.401, SD = 0.476) than the participants in the control group (Mean = 2.809, SD = 0.677), $t(38) = 3.197$, $p = 0.003$, $r = 0.460$ (Figure 7.5).

ICS scale

As the scale judgement represent ordinal data, non-parametric test (Mann-Whitney U) was conducted to compare social closeness of two groups. The result shows that participants in the scenarios where they could see "Stickers" felt significantly higher closeness (M*dn* = 3.0) between themselves and other drivers on the road than the participants in control group (M*dn* = 2.0), $U = 125.5$, $p = 0.036$, $r = 0.332$ (Figure 7.6).

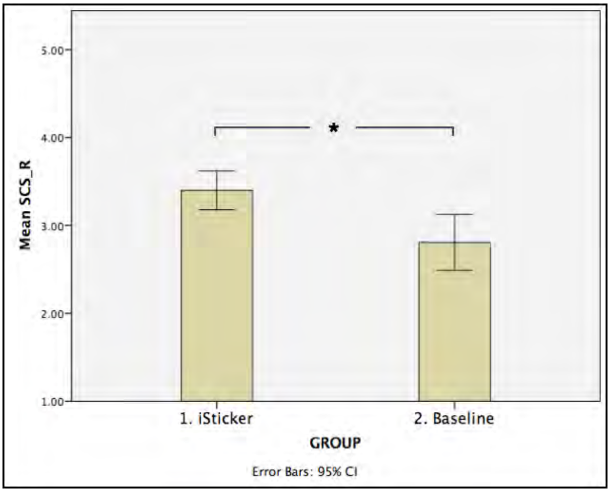


*Figure 7.5 Mean of the result of SCS-R scale (ranges from 1-5). * indicates significance.*

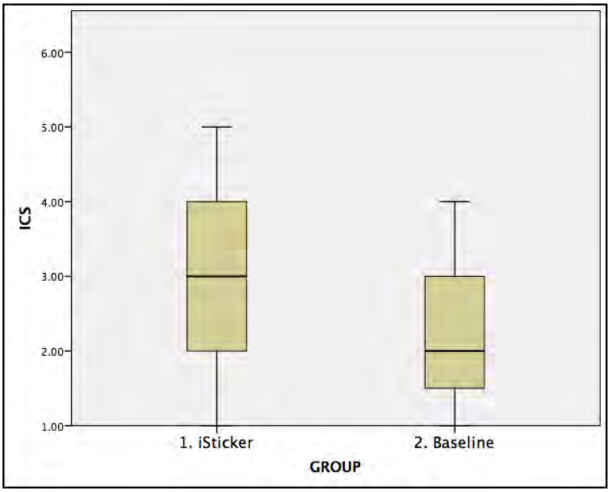


Figure 7.6 The result of ICS scale (ranges from 1-6).

Mental effort

As the RSME scale judgement represents ordinal data, a non-parametric test (Mann-Whitney U) was conducted to compare mental effort of two groups. There is no significant different between the two groups. The median mental effort of the group where participants could see others' sticker was 31.000, compared with the control group whose mean was 23.000 ($U = 183.0$, $p = 0.645$).

Appeal

This questionnaire provides insight into the appeal of this application. Based on the Independent T-test, the result of the appeal questionnaire in group 1 (Mean = 5.843, SD = 0.553) is significantly higher than in group 2 (Mean = 2.356, SD = 0.840): t (38) = 15.506, p<0.001, r = 0.929.

Liking of "Stickers"

This scale, which ranges from 1 to 11, shows how participants liked the "stickers" appearing on the others' cars. Most participants gave a high score of preference (Mean = 9.050, SD = 1.848). Only one participant gave a score below 6. The result indicated that most participants like the other's "stickers" in the experiment.

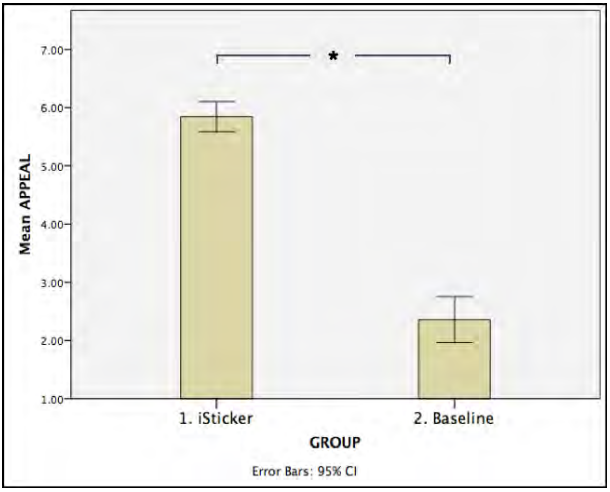


*Figure 7.7 Mean of the result of Appeal questionnaire (ranges from 1-7). * indicates significance.*

Correlations

Spearman's rho correlation was calculated between SCS-R scale, ICS scale, appeal, workload and participants' liking of Stickers. There were significant positive correlations between the results of the SCS-R scale and the ICS scale (rho = 0.350, p = 0.027), between SCS-R scale and Appeal questionnaire (rho = 0.418, p = 0.007), and between ICS scale and Appeal questionnaire (rho = 0.445, p = 0.004) (Figure 7.8). There were no significant correlations between other items.

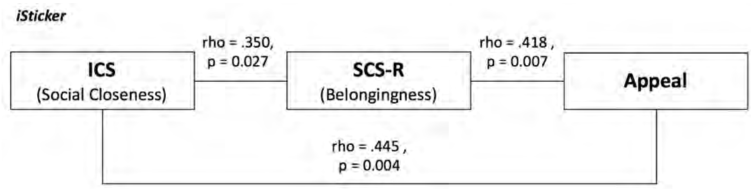


Figure 7.8 Correlations between ICS, SCS-R and Appeal questionnaire.

7.4.6 Qualitative research

In order to gain structured insights from our study, we transcribed and analysed the interview data by qualitative content analysis (Hsieh & Shannon, 2005). In this section, we report on the results of in total 258 textual descriptions. The descriptions were coded by the first author using the following three themes: 1) Factors influencing the acceptance of the concept, 2) Factors influencing the social closeness and 3) Factors influencing the distraction on driving behaviour.

Table 7.1 Categorization of textual descriptions with the numbers of quotes and participants for each (sub-)category indicated in the parentheses.

Category (N of quotes/participants)	Sub-Category (N of quotes/participants)	Exemplar quotes
Theme 1: Acceptance: Which factors influence the people's attitude of the concept?		
General Description (23/20)	Positive (20/17) Negative (3/3)	*"Actually, I like it a lot. It's funny to see another person is also interested in 'Star Wars'".*
Positive Factors (52/13)	Reducing boredom and loneliness (34/15)	*"It gives us opportunity to do something instead of just driving."*
	Improve driving behaviour (7/5)	*"Rather than 'horning' him. I will be more tolerant, not get angry."*
Negative Factors (16/9)	Distraction (6/3)	*"As a co-pilot, you can do anything you want. As a co-pilot, you can socialize. But as driver, you must put your eyes*

		on the roads, otherwise you crash."
	Necessity (2/1)	*"But how does it relate to driving"*
	Limitation of simulation (2/2)	*"But in this scenario, I think there is a log in the screen"*
	No further interaction (2/3)	*"Just cartoon, there is no further interaction…not so interesting"*

Theme 2: Social bonding: Which factors influence the social closeness?

Existing Social Bonding and related reasons (24/14)	Similarity of Stickers (16/8)	*"I don't know what person the other guy is, but I know I do have a relation with him because he is also a Star Wars person."*
	Others (8/7)	*"When it appears, it would be different."*
No Social Bonding and related reasons (11/6)	Not strong bonding by sticker (9/6)	*"I wouldn't say exactly related... The movie interest maybe too small to …really think of …relation."*
	Others (2/2)	*"It just appears like any other things passing by."*
Behaviour (17/9)	Looking at face (9/8)	*"I just following that person, and being like, okay, being curious to see who is this person."*
	Following (5/4)	*"He drove so slow, I was waiting him. I contact him physically."*
	Overtaking (3/3)	*"He tried to give some feedback to me, kept distance with me, I tried to horn, overtake him etc. …But I think he knows me, and tried to interact with me…"*
Increasing Social Closeness (56/17)	Overlapping of the profiles (37/12)	*"For example, you can give several badges all together, the sports, super hero, at least two*

		or three, then your feel more related."
	Further interaction (19/12)	*"...So I just click on the screen and say 'hi' and start the conversation, could you let me know what place to visit or something."*

Theme 3: Which factors influence the distraction on driving task?

General judgment (22/20)	No distraction (12/12)	*"...this just a few seconds, so I don't think it's distracting. That's just like navigation."*
	Certain distraction (8/7)	*"It is a sort of distracting over there. Because I found myself was not continually looking at the screen showing who has a badge."*
	A lot distraction (1/1)	*"It is too much distraction for me."*
Interface (18/7)	Mapping stickers (18/7)	*"It was a big difficulty, especially when the car is ahead and there is a bit of traffic. I couldn't get from the screen which one it was."*
	Design detail (/3)	*"I have to pay attention to recognise the other's figure."*
Scenarios (19/8)	Density of traffic (5/5)	*"Yes, but it depends, in some scenarios with a lot of traffic, it may distract me. But in the traffic jam or red light... very appropriate."*
	Traffic jam or traffic light (6/4)	*"In the traffic jam, rush hours, it is very appropriate."*
	Speed of vehicle (3/2)	*"I think the speed is also an important thing."*
	Others (5/4)	*"If there are cars on the all three lanes maybe it is kind of distracting."*

Acceptance

Ninety-one quotes in this theme provide insight on peoples' general idea of this application. Participants were firstly asked to "describe this application", then to explain the reason of the descriptions. Three dominant categories were generated from the analysis of the quotes: *general description, positive factors* and *negative factors.*

Category 1: Description

Twenty-three quotes from twenty participants showed peoples' general impression of this application. Almost all of the quotes (17 from 20 participants) were positive worded, which indicated that this application got a high acceptance. The most used words by participants are "interesting" (seven quotes), "good" (six quotes) and "like" (six quotes).

> *"Actually, I like it a lot. It's funny to see another person is also interested in 'Star Wars'".*

Category 2: Positive factors

Fifty-two quotes from thirteen participants revealed factors that positively influenced peoples' attitude towards this application. After analysis of these quotes, two sub-categories were generated: *Reducing boredom and loneliness* and *Improving driving behaviour.*

Thirty-four quotes from 15 participants expressed appreciation of *iSticker* as it reduced boredom and loneliness of driving, especially for long journey (eight quotes from seven participants) and traffic jams (four quotes from four participants).

> *"When I am driving for hours at night, if there is someone (with the "Sticker") appearing in front of me, I would feel like be guided by him and want to get to know him."*

> *"It gives us opportunity to do something instead of just driving."*

Seven quotes from five participants described the positive influence on their driving behaviour by *iSticker*. Two participants stated that the application kept them even more focusing on the road in a long journey.

And three participants thought *iSticker* could induce them to drive more politely by providing identity information of anonymous drivers.

> *"…There is a big difference between what people should do and what people do…It was a trip from Mexico to Texas, 800 km. At first you start driving quite like a decent person… well the time passed, you don't realise that you speed up."*
>
> *"Rather than 'horning' him. I will be more tolerant, not get angry."*

Category 3: Negative factors
Sixteen quotes from nine participants are about negative factors that influenced their acceptance of this application. *Distraction* was mentioned by three participants as a disadvantage, posing an obstacle for accepting this concept.

> *"As a co-pilot, you can do anything you want. As a co-pilot, you can socialize. But as driver, you have to put your eyes on the roads, otherwise you crash."*

There are three quotes from two participants stating that only allowing to see sticker without further interaction decreased their interest to use this concept. One participant questioned the *necessity* of this concept as it is "not related to the driving activity". Two quotes from two participants mentioned the *limitation* of conducting the experiment on the driving simulator; they stated that in real life, they might be "more social". As in the experiment, they interacted with agents not real people.

Social bonding

This theme collected 106 quotes describing participants' feeling of social inclusion as well as the reasons behind it. Furthermore, quotes about the willingness of further interaction with the drivers in the same community are also included.

Most participants (14 of twenty) confirmed that *iSticker* increased their feeling of social bonding, which was in line with the quantitative data. Six participants (11 quotes) did not feel bonding with others. The quotes in this theme are divided into three categories: *existing social bonding and related reasons; no social bonding and related reasons; further interactions*

Category 1: Existing social bonding and related reasons
The most mentioned factor (16 quotes from eight participants) that influenced the social bonding was the *similarity*. They thought that others also have the same interest when they saw the stickers.

> *"I don't know what person the other guy is, but I know I do have a relation with him because he is also a Star Wars person."*

> *"You feel related to the other driver, it's good."*

Category 2: No social bonding and related reasons
Six participants (11 quotes) did not feel much social bonding with other drivers. Six of them stated that the relatedness brought just by stickers is not strong enough, and that further interaction and more overlapping of their profile would increase their feeling of connectedness.

> *"I wouldn't say exactly related... The movie interest maybe too small to …really think of …relation."*

Category 3: Behaviour of participants
Seventeen quotes by nine participants concerned the behaviour they took to the drivers with stickers. Eight participants said that they tried to look at the face of the drivers in their community when passing by, and three of them intentionally overtook the car with stickers. And four participants tried to follow the car with stickers.

> *"I just following that person, and being like, okay, being curious to see who is this person."*

> *"Naturally you are kind of looking at it, you want to see what kind of person is in the car."*

> *"He drove so slow, I was waiting him. I contact him physically."*

Interestingly, one participant thought the agent in the scenario had certain intelligence to "give some feedback" to him, but no feedback of the agent was set in the experiment.

> *"He tried to give some feedback to me, kept distance with me, I tried to horn, overtake him etc. …But I think he knows me, and tried to interact with me…"*

Category 4: Increasing social closeness

Fifty-five quotes from 17 participants were related to how the design could be changed to increase their feeling of social bonding, which were categorised in two categories: *further interaction* and *overlapping of the profiles*.

Twelve participants (19 quotes) were willing to have further interaction with the drivers with stickers. Nine of them just wanted to have simple contact such as saying "hi", but four persons said that they would like to start a conversation with others. One participant wanted further contact and establishing a connection after the journey.

> *"…So I just click on the screen and say 'hi' and start the conversation, could you let me know what place to visit or something."*

Thirty-seven quotes from twelve participants said that revealing more overlap of their profile would increase the social bonding.

> *"For example, you can give several badges all together, the sports, super hero, at least two or three, then your feel more related."*
>
> *"I wonder how he likes the story, is he enthusiastic about it just like me? Which part does he like? Did he only watch the movie or read the book?"*

Four participants wanted to see the stickers from other communities, for example, the sticker taken by many drivers, as they wanted to "know the trend". Twelve quotes from eight participants stated that stickers relating to "local events" would be more acceptable.

> *"Maybe according to the city or a popular character would be better."*
>
> *"It is quite interesting that we could drive together for the match. Let's just say, if it is in the football match, then you know they will going to the same direction."*

Distraction

Fifty-nine quotes from twenty participants described the distraction issues, which further separated into three sub-categorisations: *general judgments*, *interface and scenarios*.

Category 1: General judgment

Twenty-two quotes from all the participants expressed a general opinion about distraction. Twelve participants did not feel that their driving task was distracted. Eight participants confirmed that they felt at least a little distraction. Seven of them said that the distraction is endurable, and one of them felt severe distraction.

> *"…this just a few seconds, so I don't think it's distracting. That's just like navigation."*

> *"It is a sort of distracting over there. Because I found myself was not continually looking at the screen showing who has a badge."*

Category 2: Interface

Eighteen quotes by seven participants mentioned distraction related to interface problems. Seven participants said that mapping the sticker-car in the scenarios to the icon in the screen was difficult. Some participants suggested to show the colour or type of the vehicle in screen for better matching.

> *"It was a big difficulty, especially when the car is ahead and there is a bit of traffic. I couldn't get from the screen which one it was."*

> *"I could see those cars. But I don't know it is a van or motor bike or anything… there are two or three cars, but all the three are the same so, I don't know it is a big vehicle or small vehicle."*

Other quotes were about the details that were shown in the interface. For example, one participant stated that the "dot" representing the other car was too big, and there were no lanes in the interface.

Category 3: Scenarios

Nineteen quotes by eight participants mentioned distraction due to the scenarios. Five participants said that it related to the density of the traffic.

Four participants stated the concept is appropriate while waiting for traffic light or trapped in traffic jam.

> *"Yes, but it depends, in some scenarios with a lot of traffic, it may distract me. But in the traffic jam or red light… very appropriate."*

7.5 STUDY TWO: MUSICHOUND

7.5.1 Concepts and rationale

MusicHound: Music as a social bond connecting drivers

Enjoying and creating music is often a collective activity (Håkansson, Rost, & Holmquist, 2007). Music can meet our social need, and plays an important role in how we identify and express ourselves (Frith, 2002). Sharing music with others often fills a social function. The content of music may be used to establish new social links and maintain existing ones. Nowadays, thanks to the widespread connectivity of internet and location based services, portable devices can also be used to connect with other people in common space. Various projects have been conducted to investigate sharing music in urban environment.

The ethnographic project *Underground* (Bassoli, Brewer, Martin, Dourish, & Mainwaring, 2007) provides an application for music exchanging in London Underground. It allows artists to upload songs in specific points, and the user can download these songs from these points or from collocated users, browse profiles of users in the vicinity, and send messages. The *Compass* (Tanaka, Valadon, & Berger, 2007) project uses mobile phones to exchange music with collocated people. A compass metaphor is applied as user interface on the cell phone to visualize nearby networks, people, and music. The application enables users to exchange music when both users are within Bluetooth or wireless network transmission range. The mobile application *Capital Music* (Seeburger, Foth, & Tjondronegoro, 2012) enables real-time sharing of song choices with collected urban dwellers. People can exchange metadata of music as well as the artwork of the currently played song with nearby users. Besides, this application enables users to send text messages and "Like" messages.

As the automobile is the most popular and frequently reported location for listening to music (Brown, Sellen, & Geelhoed, 2001), we utilise the music as a media to establish social bonding on the road. The concept *MusicHound,* is described as follow:

> *Donald has been driving alone for 2 hours on the highway. There are not many cars on the road at this moment, the long tedious journey makes him a little bored and lonely. He decides to open the "Music-Around-Me" application of his car. Then the system scans his music list to analyse his preference of music for better matching. Several minutes later, when approaching a car in front of him, a slight rhythm of "Only Love" is rising in his cabin. The text indicates that the music is played by the front car. "It's my style", he thinks. So he waves his hand to get the song playing in his own car. Then these two cars start to play the music together.*

MusicHound links to drivers' profile of social media and matches drivers based on their music taste. If a nearby driver is playing music, other drivers who have the similar music taste can hear that and "get" the music to play in their cars.

7.5.2 Apparatus

The concept *MusicHound* was prototyped in a same driving simulator as study 1 (Figure 7.1).

7.5.3 Design and prototype

Similar to study 1, the interface was designed to show three layers of information: *1) Geography layer*, *2) a vehicle layer* and *3) notification layer* (Figure 7.9). However, instead of stickers of other cars, an icon representing the sharing-music car and the visual animation of synchronizing music was shown in the *notification layer*.

After a meta-analysis of 43 studies, Burke et al. (2006) concluded that in the visual-auditory system, sound captures the user's attention more quickly with less workload than visual cues alone and leads to quicker reaction times and better performance scores. Therefore, for the system output, an auditory-visual feedback system was adopted. Two speakers were implemented in the front of the simulator not only to play the music, but also to deliver auditory feedback of two kinds of information:

- Availability to get music. When a driver who shares music is approaching, the volume of music is increasing according to the distance between the participant and the sharing-music car.
- Confirmation of "get" music from other vehicles: A sound clip that represented a confirmation message was selected as an auditory feedback for confirmation of successful "got" other music and the volume of the music increased to standard value.

Figure 7.9 User interface design. 1) Geography layer; 2) Vehicle layer; 3) Notification layer

7.5.4 Procedure of getting-music operation.

For confirmation of receiving music, gestural interaction was adopted. The use of gestural interfaces for in-car interaction can reduce visual demand and thus increase safety (Riener, 2012). Zobl et al. (2003) suggested that a gestural command style was more intuitive and simple than knobs and touch screen command styles. Another advantage of gesture is that it does not require physical interaction with another surface (Fujimura et al., 2013). We utilized the "wave hand in" gesture to represent the operation of getting others' music (Figure 7.10).

The flow of getting others' music can be separated into 3 steps (Figure 7.11):

- Step 1: If there is no recommended music playing by surrounding drivers, the interface shows the own car as well as nearby cars on the road.
- Step 2: If there is a nearby car playing music matching the driver's music preference, an icon appears on top of the corresponding car on the map. Furthermore, the speakers of the participant start to play the recommended music in low volume.
- Step 3: Participants wave their hand in front of the LeapMotion sensor to enable other driver's music to play in their own car. After getting the music, an auditory feedback is played to confirm the transmission and the volume of the music increases at the same time. Besides, a visual effect appears and a white line between the two car emerges to inform participants with which car they are synchronizing music.

7.5.5 Evaluation

Evaluation Setup

40 participants were involved in this study. The participants were divided into two groups, with Group 2 acting as a baseline condition for Connectedness and Social inclusion on the road. In order to get equal groups we balanced: gender, driving experience and age. There were 14 males and 6 females in the first Group, 13 males and 7 females in the second Group. The average age of the first group was 25.80 (SD 3.98) and the second group 25.25 (SD 4.03). They had quite equal driving experience, measured in the amount of years that the participants had a driver's license: 5.93 (SD 3.53) for the first group and 5.50 (SD 3.53) for the second group. For participating in the experiment, each of them received a 5-euro reward.

Figure 7.10 Wave hand in to "get" the music of other cars.

Recommended music

Before the test, each participant was asked to provide three songs they favoured while driving. Then these songs' names were put into the music website Spotify (www.spotify.com). The "Recommend Songs" feature was used to generate one related song, which would be played in the experiment, for the purpose of simulating the recommended music in the application.

Dependent variables

The same questionnaires as in study 1 were used to evaluate the belongingness, social closeness between participants and other drivers, mental effort of the application and the appeal of this application: Revised Social Connectedness Scale (SCS-R), Inclusion of Community in Self (ICS) scale, Rating Scale for Mental Effort (RSME) and Appeal questionnaire. Furthermore, a Likert scale about how participants liked the suggested music playing in the scenario was also included, for the purpose to examine the accuracy of the recommendation.

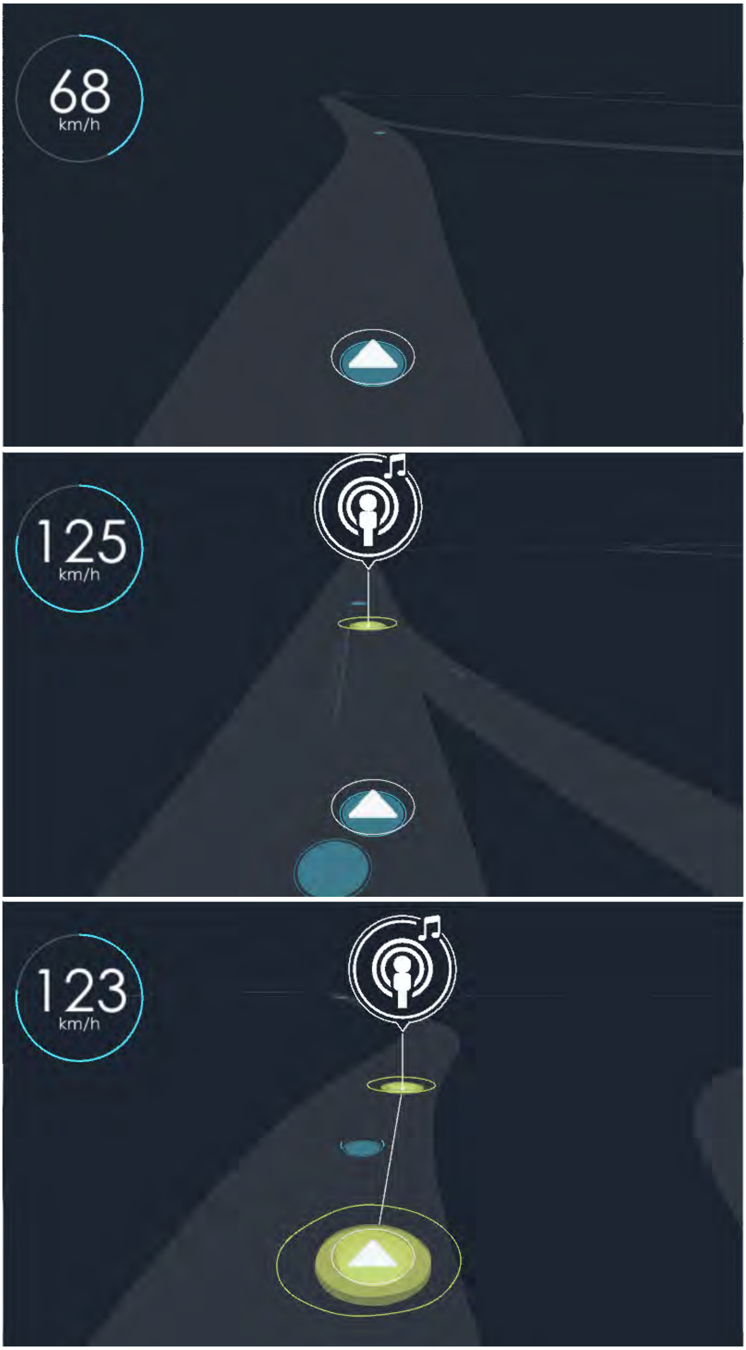


Figure 7.11 Interface of 3 steps of getting others' music.

Scenario

The same highway scenario as in study 1 was used for this experiment. The total duration of the scenario was 10 minutes. The turn-by-turn navigation was disabled in this study. Participants were told to driving straight and not leave the highway.

Experiment Procedure

Before the formal test session, each participant was invited to drive in the simulator in a free driving mode for 10 minutes with the purpose of getting familiar with the driving simulator. Then each participant from group 1 was introduced to the concept of the music sharing system. Furthermore, he/she was asked to practice "get"-ting music from other cars by waving hand in front of the LeapMotion.

Before the test, participants were instructed to accept ("get") all the music emerging in the scenario. There were three cars which played recommended music appearing in three different segments of the road for each participant in group 1. After the participant accepted the music, it played for 2 minutes then faded out. For group 2, acting as a baseline condition, there was no other car playing music but the music played three times at the same locations for the same duration as group 1. Furthermore, the interface of 3D maps remained. After the driving session, the participants of each group were asked to fill in the questionnaire and people in group 1 had a semi-structured interview.

7.5.6 Results

SCS-R scale

An independent T-test was conducted to compare the social connectedness level of the two groups (Figure 7.12). The results showed that the participants who could see others' music felt significantly higher belongingness (Mean = 3.376, SD = 0.687) than the participants in the control group (Mean = 2.757, SD = 0.714), $t(38) = 2.793$, $p = 0.008$, $r = 0.413$.

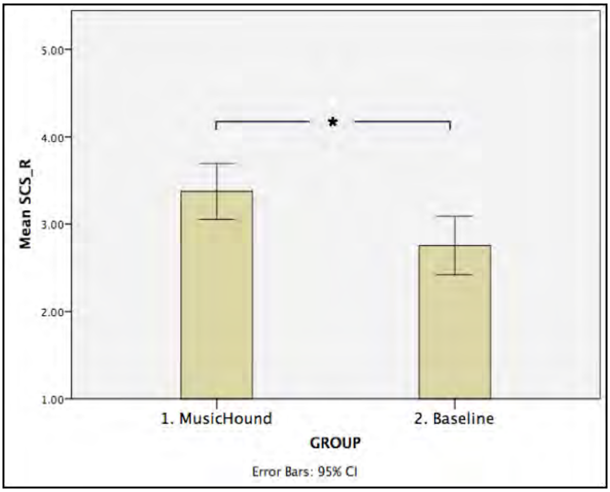


*Figure 7.12 Mean of the result of SCS-R scale (ranges from 1-5). * indicates significance.*

ICS scale

Based on the Mann-Whitney U Test, participants in the scenarios where they could get music felt significantly higher closeness (M*dn* = 3.0) between themselves and other drivers on the road than the participants in the control group (M*dn* = 2.0), U = 127.5, p = 0.044, r = - 0.371.

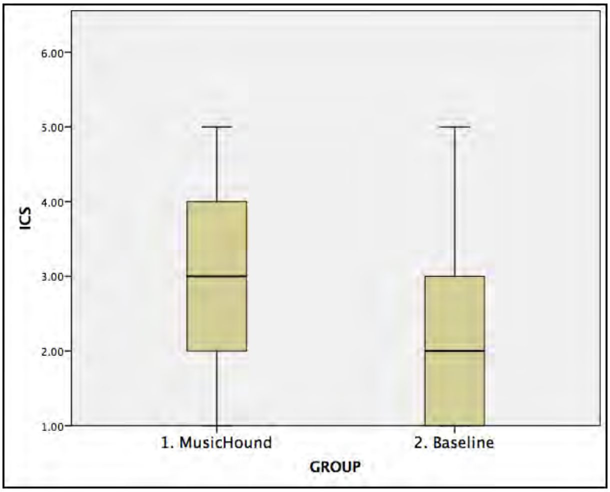


Figure 7.13 The result of ICS scale (ranges from 1-6).

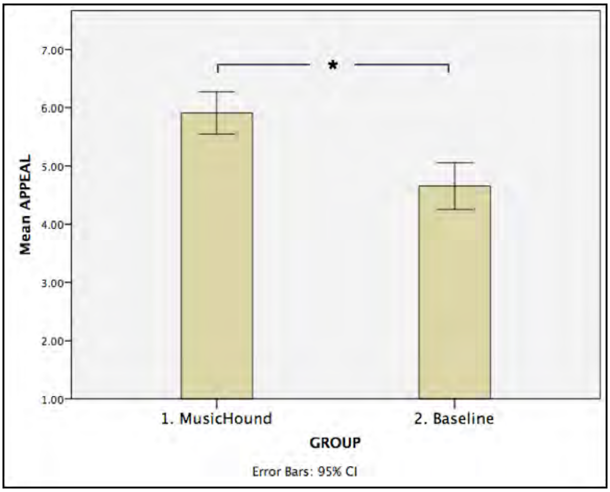


*Figure 7.14 Mean of the result of Appeal questionnaire (ranges from 1-7). * indicates significance.*

Mental effort

As regards the mental effort of participants, which was measured by the RSME scale, there is no significant difference between the two groups based on the Mann-Whitney U Test. The mean mental effort of the group where participants could get music was 34.800 with a SD of 21.750, compared with the control group whose mean was 29.900 with a SD of 15.851.

Appeal

This questionnaire provides insight into the appeal of this application. Based on the Independent T-test, the result of the appeal questionnaire in group 1 (Mean = 5.913, SD = 0.774) is significantly higher than in group 2 (Mean = 4.656, SD = 0.859): $t(38) = 4.859$, $p<0.001$, $r = 0.619$ (Figure 7.14).

Liking of music

This scale, which ranges from 1 to 11, shows how participants liked the music playing in the experiment. Most participants rated a high score of liking for both group 1 (Mean = 8.750, SD = 2.197) and group 2 (Mean = 8.650, SD = 1.843). The result indicated that most participants liked the music playing in the experiment and the preference of music in group 1 and group 2 were quite close.

Correlations

Spearman's rho correlation was calculated between SCS-R scale, ICS scale, appeal, workload and participants' liking of music they got. There were significant positive correlations between the results of the SCS-R scale and the ICS scale (rho = .684, $p < 0.001$), between SCS-R scale and Appeal questionnaire (rho = .411, $p = 0.008$), and between ICS scale and Appeal questionnaire (rho = .318, $p = 0.046$) (Figure 7.15). There were no significant correlations between other items.

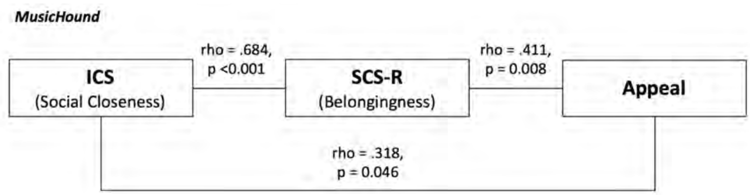


Figure 7.15 There are significant correlations between ICS, SCS-R and Appeal questionnaire.

7.5.7 Qualitative research

In order to gain structured insights from our study, we transcribed and analysed the interview data by qualitative content analysis (Hsieh & Shannon, 2005). In this section, we report on the results of in total 221 textual descriptions. The descriptions were coded by the first author using the following three themes: 1) Factors influencing the Acceptance of the concept, 2) Factors influencing the Belongingness 3) Factors influencing the distraction on driving behaviour. (Table 7.2)

Table 7.2 Categorization of textual descriptions with the numbers of quotes and participants for each (sub-)category indicated in the parentheses.

Category (N of quotes/participants)	Sub-Category (N of quotes/participants)	Exemplar quotes
Theme 1: Acceptance: Which factors influence the people's attitude of the concept?		
General Description (28/20)	Positive (26/19) Negative (2/1)	*"It's very nice, very interesting. (I am) looking forward to see it in the real road".*
Positive Factors (36/13)	Social Activity (18/9)	*"I looked at the screen, there is a tag on the car, then I know, yes, another prey is coming!"*

	Finding Music (9/7)	*"It gives you a little pleasure that you haven't listen to the music maybe for 1 or 2 years, then suddenly it's a nice song."*
	Improve driving behaviour (9/4)	*"Your mind tends to add up some value, not pay attention on the road while you are alone…it doesn't distract me but draws my attention back to the road."*
Negative Factors (14/7)	Distraction on driving (6/3)	*"Actually, I have to be 100% focus on driving. I don't have like 20 years driving experience… But that's about me. If I have 10 years' experience), it would be definitely changed."*
	Limitation of Simulator (4/2)	*"The simulator brought me a little bias about the scenario. Maybe in real situation I feel better."*
	Unnecessary (3/2)	*"…but you have internet all the time, you can find music and play the music at any time."*

Theme 2: Social bonding: Which factors influence the social connectedness and closeness?

Existing Social Bonding (34/15)	Similarity of Music Taste (16/8)	*"…that's maybe the only thing I have common with other drivers at time."*
	Synchronization of Music (18/12)	*"(The music) it's not my style, but I like the fact that … you are listening to the music with people around you. I really think that creates a little bonding to the others."*
No Social Bonding (12/5)	Enjoying Music Only (9/4)	*"…I just focus on enjoying the music itself. It just like you pass by a shop and take a book. You don't have so much relatedness with the shop."*

	Others (3/2)	*"if I experience it in real situation and socialized with real people, maybe I would like it better."*
Theme 3: Which factors influence the distraction on driving task?		
General judgment (21/20)	Positive (12/12)	*"I think it is pretty clear which car is playing the music."*
	Negative (9/8)	*"Yes, I feel a little distraction."*
Visual interface (27/12)	Positive (21/9)	*"It was just like I am going with the navigation system."*
	Negative (6/6)	*"I have to pay 1 second to match the dot in the small screen to surrounding car."*
Auditory feedback (8/7)	Positive (4/3)	*"I hear the music then wave my hand, that's it."*
	Negative (4/4)	*"For the interaction, maybe when the car is going further sound should get lower. While in the simulator, there is no feeling that the car is going further."*
Gestural interaction (18/10)	Positive (10/6)	*"The waving part is perfect, it's very straight forward."*
	Negative (8/4)	*"When I try to move my hand at first time, I just feel the car go to a little right of the road because I didn't hold the steering wheel."*
Suggestions (23/8)		

Acceptance

Quotes in this theme provide insight on peoples' general idea of this application. Participants were firstly asked to "describe this application", then to explain the reason of the descriptions. Three dominant categories were generated from the analysis of the quotes: *general description, positive factors* and *negative factors.*

Category 1: General description

Twenty-eight quotes from twenty participants showed people's general impression of this application. Almost all of the quotes (26 from 19 participants) were positively worded, which indicated that this application got very high acceptance by people. The most used words by participants are "good" (eight quotes), "like" (six quotes) and "interesting" (four quotes).

> *"It's very nice, very interesting. (I am) looking forward to see it in the real road".*

Category 2: Positive factors

Thirty-six quotes from thirteen participants revealed factors that positively influenced peoples' attitude towards this application. After analysis of these quotes, three sub-categories were generated: *Social activity, finding music* and *Improving driving behaviour.*

Eighteen quotes from nine participants were related to social activity. Five participants were very curious of others' music and thought it was more interesting to get music in this way. These comments indicated that people were interested in adding social features to the vehicle.

Nine quotes from seven participants described that the music sharing through *MusicHound* provided another way to find music. One participant said that the *MusicHound* was "like a friend sitting in the passenger's seat and searching songs for you".

Nine quotes from four participants described the positive influence on their driving behaviour by *MusicHound*. Surprisingly, instead of distraction, six quotes from three participants stated that the application kept them even more focusing on the road in a long journey. Besides, two participants thought *MusicHound* could cultivate pro-social driving behaviour by providing the identity of anonymous others and the music sharing could "calm them down".

> *"Your mind tends to add up some value, not pay attention on the road while you are alone…it doesn't distract me but draws my attention back to the road."*

Category 3: Negative factors

Fourteen quotes from seven participants mentioned negative factors that influenced their acceptance of this application, which fall into three sub-categories: *Unnecessary, Distraction on driving* and *limitation of driving simulator*.

Three quotes from two participants compared MusicHound with other media players in the vehicle and contested the *need* for getting music from other drivers, as "playing recommended music" had already become a standard feature in lots of online music such as Spotify.

> *"...but you have internet all the time, you can find music and play the music at any time."*

Distraction was also mentioned by two participants as a disadvantage, which seemed highly related to their driving age. Four quotes of two participants mentioned the *limitation* of conducting the experiment on the driving simulator. They stated that it did not provide accurate feelings of driving, especially on the perception of dangers, which may lead to more aggressive driving.

Social bonding

This theme collected 46 quotes describing participants' feeling of social inclusion as well as the reason behind it. Most participants (15 of twenty) confirmed that *MusicHound* increased their feeling of social bonding, which was in line with the quantitative data of the social inclusion questionnaire. Only five participants (twelve quotes) did not feel social inclusion in others. The quotes in this theme were divided into two categories: *existing social bonding and related reasons; no social bonding and related reasons.*

Category 1: Existing social bonding and related reasons

Anonymity and lack of interaction hide the personality and identity of drivers on the road. As mentioned above, people were very interested in adding social features instead of interacting monotonously with other road users. *MusicHound* is a tool to expose drivers' profile without leaking sensitive information. "*Surrounding drivers become alive"* when they were sharing music.

One of the factors (16 quotes from eight participants) that influenced the social bonding was common preference of music. They felt “attached to” others when others played the music they liked.

> *“…that’s maybe the only thing I have in common with other drivers at that time.”*

Besides the similarity of the music taste, listening to music simultaneously with others seemed also essential for enhancing social connection. Twelve participants said that they enjoyed synchronizing music with others. One participant did not like the music playing in the scenario, however, he thought that he related to others as well.

Category 2: No social bonding and related reasons

Five participants (twelve quotes) felt little social bonding with other drivers. They enjoyed the rhythm of the music but did not care about who shared the music. Some participants even saw the visual interface that showed the source of the music as unnecessary and distracting. In addition, one participant mentioned that she did not feel that she was “in a real social scenario” and did not see other drivers as “real people”. Another participant said that she did not feel much bonding between others as she did not like the suggested music.

> *“…I just focus on enjoying the music itself. It is just like you are passing by a shop and take a book. You don’t have so much relatedness with the shop.”*

Distraction

Seventy-four quotes in this theme described the participants’ opinion of driving distraction caused by *MusicHound*. Four dominant categories emerged from the analysis: *general judgment, visual interface, auditory feedback and gestural interaction.* Each category contained positive and negative descriptions about the distraction by MusicHound.

Category 1: General judgment

Twenty-one quotes from twenty participants described the general opinion about distraction. Twelve participants thought MusicHound did not distract from their driving task. Eight participants confirmed that they felt a little distraction. Among these four participants had less than four years driving experience. In opposite, the participants who did not feel distraction all had more than five years driving experience.

> *"Yes, I feel a little distraction."*

Category 2: Visual interface

Twenty-seven quotes from twelve participants mentioned the visual interface of MusicHound. Twenty-one quotes described the positive aspect of this interface. Nowadays, navigator software is widely installed on various devices such as smart phone, digital instrument or screen in the console. Drivers get used to mapping the roads, intersection and buildings of the navigation to the real world outside the windshields. Therefore, six participants said that they were familiar with daily usage of a navigation system and did not feel much distraction by MusicHound. Thirteen quotes described positively the detail of interface design, including the icon, map, and visual effect of music.

> *"It was just like I am going with the navigation system."*

On the other hand, six quotes from six participants described the negative aspects of the interface. One participant said it took one second for him to "match the dot in the small screen to the surrounding car"; another participant thought the visual effect of music was "cool" and enhanced their feeling of resonance with others, but "it was too much" and distracted from the driving task.

Category 3: Auditory feedback

Eight quotes from seven participants described the auditory feedback of the MusicHound, four of them were negative. Participants mainly complained about the insufficiency of information that auditory feedback contained. In the real world, the auditory sense can not only be used to represent the meaning of an event, but also the position. As the human ears are located at either side of the head, the so-called binaural effects enable the humans to better determine the location of a sound source in terms of azimuth (Barfield, Cohen, & Rosenberg, 1997). Participants suggested spatial auditory feedback: the sound could be delivered spatially through multiple speakers to indicate the spatial location of the music source.

Category 4: Gestural interaction

Eighteen quotes from ten participants described the gestural interaction. Half of the participants (six participants with ten quotes) accepted the waving hand interaction comparing with their own controller of music player in the vehicle. However, nearly half of quotes (eight quotes from four participants) held a negative attitude toward the interaction of waving the hand to get music. Three participants mentioned the danger of raising one hand out of the steering wheel while the car was in a high speed. Two participants suggested other ways of input, such as putting a button on the steering wheel or speech input.

> *"When I try to move my hand at first time, I just feel the car go to a little right of the road because I didn't hold the steering wheel."*

Suggestions

Besides the three themes, 23 quotes described other aspects of this application, such as the mechanism of sharing music, privacy and whether willing to sharing music etc.

One participant suggested a rewarding mechanism, which enables drivers to profit from sharing music if it is "caught" by lots of other drivers. Another participant recommended a filter which enables drivers to choose different styles of music. Three participants mentioned that they were willing to share music and expected others to get their music as well. They did not think the music preference is specific enough to leak their private information.

Another interesting finding was the attitude of further interaction beside sharing music. Three participants were quite positive about sharing music and would like to have further social interaction on the road, for example speeding up to pass a driver who is sharing the music and "wave hand or smile to him". However, they all did not want further to contact with these people afterwards, for example, joining them on Facebook. As participant 2 said, "I don't want to know where he lives or where he is heading. That's just a strange company for small period of time".

7.6 CONCLUSION AND DISCUSSION

In this study, we investigated how drivers feel about establishing social bonding with the anonymous drivers by exposing their profile information. The following hypotheses were evaluated:

- H1: “People hold a positive attitude towards these concepts.” H1 is supported by both quantitative data and qualitative research: Participants who can see others’ stickers or “get” music gave higher score in the appeal questionnaire; and most of the participants held positive attitude to these concepts.
- H2: “The applications have positive influence on social closeness and belongingness.” This hypothesis is also supported. According to the result of SCS-R scale and ICS scale, people feel more social closeness and belongingness if they can see others’ stickers or “get” others’ music. The interview results also show that most of the participants (14 of 20) felt there was social bonding between them and other drivers on the road.
- H3: “The presence of interaction between drivers will contribute to the social closeness and belongingness.” H3 was supported by the qualitative research. Based on the results of the interview, most of the participants of *iSticker* suggested to add digital interaction. More than half of the participants in *MusicHound* appreciated the feature of synchronising music with others.
- H4. “The application does not distract from the primary driving task.” The results do not support H4. According to the RSME scale, there is no significant difference between two groups. However, the results of the interview show that more than one third of the participant felt certain distracted, although only two of them stated that the distraction is unacceptable and that it is unsafe to use this concept.

Generally, the result is in line with the self-categorization theory, which suggests that the feeling of being group member can be founded upon shared characteristics, or similarities, among their members (Turner, Hogg, Oakes, Reicher, & Wetherell, 1987). And groups can provide their members with feelings of belonging (Gardner, Pickett, & Brewer, 2000). The quantitative result shows that there are correlations between social closeness, belongingness and appeal of the journey. However, it seems that the social bonding is not the only factor that contributes to belongingness. According to Baumeister et al (Baumeister & Leary, 1995), in addition to perceived social bonding, positive interaction and contact also contribute to the belongingness between people. In *iSticker*, there is a social bonding between participants and other drivers who is in the same sticker-community. But there is no further interaction between them in the digital layer. People tried to look at the other drivers, follow and overtake them for physical "contact". In the following interview, almost all the participants (18 of 20) would like to have digital interaction with other drivers, which indicates the needs of further interaction. It is also supported by the interview result of *MusicHound*, which shows that more than half participants (12 of 20) appreciated the synchronisation of music with others. As some participants mentioned, when they "got" others' music and enjoyed it together with others, they felt that they were "dancing with them".

On another side, the qualitative results suggest that the concepts reduce driving aggression by increasing social closeness between drivers, which confirms previous research (R. R. Ratan & Tsai, 2014)(Nagler, 2013). By the digital augmentation, the drivers have the opportunity to establish links to the drivers that they encounter, which may evoke the empathy and increase trust, and decrease the incidence of aggressive driving behaviour. In our case, the participant feels closeness not only by receiving other's identity information, but also by exposing information: In *iSticker*, when people see others' stickers, it is also indicated that other people can see their stickers; In *MusicHound*, when people "get" others' music, they expose that they are in the same music group. As a result, the participants may recognise that their driving behaviour affects their reputation (R. A. Ratan, Chung, Shen, Williams, & Poole, 2010). In another perspective, by exposing that they are in the same group, they may more adhere to the social norms of this group, which regularise the behaviour (Hogg & Terry, 2000). However, further experiments are required to validate these assumptions.

Besides, the in-depth interviews also revealed another benefit that contribute to the appeal of the application: Eliminate *boredom*. Mikulas et al. (1993) defined *boredom* as a “state of relatively low arousal and dissatisfaction, which is attributed towards an inadequately stimulating environment”. Boredom often happens during long time journeys on the highway, which may lead drivers to increase their speed for seeking sensations or diverting their attention away from the driving task (Fuller, 2005). According to the interview, *MusicHound* and *iSticker* may provide stimulation to keep drivers’ attention on the road.

For the aspect of distraction, these applications may draw the participants’ attention back to the road in a long and boring journey. At the same time, however, interaction with other road users may also distract from their driving task. Some novel interaction design was suggested by participants, including spatial audio interface, augmented reality display on the windshield or even disabling this feature if drivers’ workload is too high. Nevertheless, social applications such as *MusicHound* and iSticker may cause minimal distraction. But it could be predicted that the technology of ADAS, autonomous driving and augmented reality will release drivers’ attention resources, which may stimulate the development of social features in vehicles.

7.7 LIMITATIONS AND FUTURE WORKS.

This study yielded rich quantitative data and vivid qualitative information by the user test on the driving simulator. However, there are several limitations to the research. Firstly, in this study, we balanced gender, age and driving age of participants for the between-group test. However, the participants’ driving behaviour, basic social connectedness and social closeness level were not balanced, which may influence comparison of the data in two groups. Secondly, participants’ driving behaviour and emotional status may be biased by the limitations of the driving simulator. The performance of manoeuvring the vehicle may be different in real world. Moreover, “others” who share music may have been seen as a computer agent rather than real person, which make the simulated scenarios different from a real social situation. Fourthly, each driving session only lasted 10 minutes, therefore this study was not able to investigate participants’ attitude towards this application in long term. At last, subjective questionnaires and qualitative content analysis were adopted for investigation in this study. However, several objective data such as bio-signal (heart rate variability, skin conductance etc.), gaze tracking and facial expression recognition and driving behaviour data (acceleration, speed and brake etc.) could also be used to evaluate participants' feedback of this application.

In this study, we utilised two novel applications as probes to explore the possibility of adding social features into connected vehicles in the future. The results indicate that the social bonding by digital augmentation may enhance the closeness and belongingness between drivers. Other insights are also generated by this study, such as reducing driving aggression and boredom by social interaction on the road. These will be taken up in future research.

8 Conclusion, Limitations and Future Work

In this chapter, I summarise my main contributions, give the answers to the research questions, reflect on the limitations of the experiments and set the direction for future work. Based on the result of four studies, it is concluded that the social-car applications may help to mitigate conflicts in sharing the road and reduce social isolation. However, there are some limitations of this research, such as the ecological validity of simulator research or the data collection. At last, future research directions in this domain are discussed.

8.1 CONTRIBUTIONS

Driving is a social activity as drivers need to coordinate with each other to share the road. However, physical communication has its limitation in the range and the bandwidth of exchanging information between drivers. The recent rapid development in the area of *vehicle-to-vehicle communication* technology and the broad penetration of social network services provide promising opportunities to change the current situation. This dissertation has explored the forms and mechanisms of social interaction enhanced by digital communication between drivers on the future road.

At the beginning of this thesis, the goal of this research was formulated as:

> *Designing different social-car applications to enrich the communication between drivers and positively influence driving behaviour and experience.*

First of all, I reviewed the previous research and proposed a structured framework for better interpreting the forthcoming social network between drivers. Based on this framework, all social applications on the future road can be categorised for further analysis. Then I zoomed in our study on the *synchronous-nearby* communication, as it is a research area that is barely explored. I argue that the *Synchronous-nearby* applications can be seen as a special form of face-to-face social interaction, which is facilitated by computer-mediated communication. Generally, this research systematically investigated the influence of digital augmentation on the social interaction between drivers in the *synchronous-nearby* scenarios. The results indicate that communication in the physical layer and digital layer can be complementary with each other. By reducing anonymity or enlarging communication bandwidth, different sides of digital information can improve driving behaviour and experience.

Two specific research questions were raised to address the research goal. To conclude, I answer the research questions separately.

1) Does digital augmented communication help to mitigate the conflicts in sharing the road?

According to the causal model (DCPC, 2005), the communication difficulty between drivers is one of the car-related factors that may lead to aggressive driving behaviour. The means of communication between the drivers is limited to the signals of cars such as horn, gestures, indicator or "car body-language". Difficulty in expressing dissatisfaction, apology or appreciation between drivers, and misunderstanding of "trigger events" may arouse negative emotions and induce aggressive driving behaviour.

Application *Likes and dislikes* enlarges the communication channel by enabling drivers to send and receive appreciation and disapproval, which emphasises on appeal-side information. Furthermore, drivers can get afterwards feedback by reviewing why they get or send "like/dislike" on a website. The concept was prototyped in a driving simulator and three rounds of user tests were conducted. After analysing the objective driving performance data that were collected by driving simulator and the behavioural data that were evaluated by observers, it is supported that this application positively influences people's driving behaviour.

Participants' feedback of *Likes and dislikes* suggests that only exchanging appeal-side information (judgement) is not enough. Thus, another application *CarNote* in-depth enlarges the communication channel by providing explanation of people's fast and slow driving behaviour. It enables drivers to self-disclose information, such as being in a hurry to the hospital or unfamiliarity with the road to surrounding drivers. This concept was elaborated, prototyped in a driving simulator and a user test was conducted. The result of the experiment supports that *CarNote* positively influences two kinds of emotion between drivers: empathy and tolerance.

As a result, we conclude that drivers' conflicts in sharing the road may be reduced by digital augmentation which enlarges the communication channel.

2) Does digitally augmented communication reduce the social isolation of the drivers?

Besides the communication difficulty, anonymity is another car-related factor of aggressive driving behaviour (DCPC, 2005). Because a number of studies suggested that social closeness between drivers exerts influence on the drivers' coordination with each other (Caspi et al., 1997; P. A. Ellison et al., 1995; Gulliver & Begg, 2007; Mitrevska et al., 2012; R. R. Ratan & Tsai, 2014). In another aspect, the vehicle should not only act as a tool taking people to the destination, but also be an enjoyable space to stay in during the journey. But while sitting in the vehicle, drivers are anonymised, which decrease the relatedness and leads to social isolation. This isolated situation not only results in aggressive behaviours, but also compromises one of the basic human needs: belongingness (Baumeister & Leary, 1995). Therefore, we tried to reduce the social isolation between drivers by exchanging relationship-side information.

Previous research suggests that closeness is related to the similarity between people (Tesser & Campbell, 1980; Tesser & Paulhus, 1983). Two concepts, *iSticker* and *MusicHound* were raised to enhance the social closeness by presenting similarity information between drivers. *iSticker* enables drivers to choose virtual stickers and see nearby drivers who have similar stickers. *MusicHound* matches drivers who have a similar music taste, and allows them to share music with each other and enjoy music together. The results of the simulator experiments show that information, which establishes social bonding by matching anonymous drivers' similar interests, exerts a positive influence on social closeness and belongingness on the road. As a result, it is concluded that digital augmentation can reduce social isolation.

Application insights

To investigate the relationship between the different types of digital information and the psychological and behavioural influences on driving, thirty novel concepts were generated by the brainstorming sessions. All concepts were investigated using the Co-constructing stories method (Buskermolen & Terken, 2012). We found that driver-to-driver communication related to Safety and Efficiency is well accepted; regarding the acceptance of applications related to the Relatedness and Identity, additional information, such as transparency of relationship or the existence of the connection, is essential for the likelihood of a concept being liked.

HCI insights

Furthermore, the corresponding user interfaces of the concepts were designed and prototyped in an advanced driving simulator, which enabled participants to experience the social applications that do not appear on the current road. The results of the experiments also provided insights into the human-machine interaction (HMI) design of the driver-to-driver communication. The result of *Likes and dislikes* indicates that the combination of gesture and augmented reality display on the windshield is a promising direction for the interaction between drivers, as it does not severely influence people's mental workload, and the usability and the user experience is well accepted by participants. For the *CarNote, iSticker* and *MusicHound*, a 3D interface, which can show surrounding drivers' social information, was designed and implemented in the driving simulator. The quantitative results of the experiments suggest that the interface does not increase participants' mental workload. However, the afterwards interview results indicate that some participants felt distracted by the information delivered through the 3D interface, and an augmented reality display was suggested. Moreover, the audio feedbacks were appreciated by lots of participants as they reduce the distraction.

8.2 LIMITATIONS AND FUTURE WORK

8.2.1 Limitations

Simulation

All the studies in this research were conducted with a driving simulator in a laboratory environment, which may bias participants' driving behaviour, social activities and emotional status. It was found through the in-depth interviews that some participants felt that driving in the simulator was quite different from real life. Furthermore, some participants stated that they did not have the same emotion when "socialised" with the computer agents in the simulator as with real people.

Duration

The experiments lasted a rather short time (less than 20mins), the feedback from participants of these applications in a long journey is still unknown. Furthermore, only initial use of these applications was studied. It remains to be shown that the concepts will succeed in improving driving behaviour and experience in the long term.

Data collection

Our research utilised a simulator to collect quantitative data to measure the participants' driving behaviour, and multiple questionnaires to evaluate their experience and psychological status. Moreover, qualitative research methods, such as content analysis were also used to analyse the interview results. However, there is no objective data collected to analyse participants' emotions. For example, quantitative data such as bio-signal (heart rate variability, skin conductance, etc.), facial expression recognition and driving behaviour data (acceleration, speed and brake, etc.) could be collected to evaluate these social applications.

Information overload

In this research, our applications were tested in a laboratory environment. In real-world scenarios, the participants would receive much more information, such as navigation, phone call or listening to the radio. Furthermore, we tested four different applications separately. It is possible that people would install many social applications in their vehicles. This may cause information overload. How to coordinate different sources of information displayed to the user without creating overload and distraction still needs to be explored.

8.2.2 Future work

Influence of communication on other facets beside conflicts in sharing the road and social isolation

In this research, I evaluated the influence of the appeal side and the self-revelation side on conflicts on the road, and the relationship side on social isolation. However, other combinations of sides of communication with driving behaviour and experience have not been investigated. For example, it is suggested by previous research that the relationship between drivers influences aggressive driving behaviour (R. R. Ratan & Tsai, 2014). Future work on these perspectives may contribute a more complete picture of this domain.

HCI

Human-machine interface (HMI) and human-computer interaction (HCI) is important in facilitating social communication between drivers. This aspect was not the focus of this research, although the user tests results showed that participants accepted the design and implementation. This domain could also be further explored by applying various interaction techniques. For example, according to the user tests, the distraction of social communication on the primary driving task was a concern of many participants. The latest HCI technology and research, such as augmented reality (AR) and adaptive user interface (AUI) (Langley, 1999), may be helpful to solve the problem.

Autonomous driving

The rapid development of artificial intelligence and the gradual decrease in cost of sensors accelerate the revolution of autonomous driving. The future driving system will evolve from "driver assistance" to fully automated driving, completely piloting a vehicle through highways and urban environments. With an increasing level of automation, the roads will still be shared, only the way to share and to coordinate may differ. Social interaction between drivers to share the road may not be eliminated in a short time, but be changed to another way: instead of manipulating the cars directly, drivers control the behaviour of their cars. For example, similar with the *CarNote*, when driver set the vehicles to drive fast, they also need to inform nearby autonomous vehicles as well as the passengers inside, so that the nearby drivers could get more situational awareness and would not be confused by their cars' giving-way behaviour. Moreover, when the vehicles are no longer manoeuvred by humans, the pleasure of driving should be replaced by other activities. The social interaction between drivers may become a new entertainment. Locational mobile games, such as *Pokémon GO*, may be available inside the vehicle, and even be played by proximal drivers together. As a result, there would be even more space and opportunities for social applications in the autonomous driving age. These can be explored by future research.

Appendices

APPENDIX A: THE QUESTIONNAIRE APPLIED IN CHAPTER 6

a) Please answer the question based on your experience in the scenario

Did you notice that some drivers drove fast and pushing?

Yes *No*

Did you notice that some drivers drove slowly and hesitatingly?

Yes *No*

b) Please answer the following questions by using the scale below them

1. The people who drove *fast and pushing* deserve a fine

○ Strongly Agree ○ Agree ○ Neutral ○ Disagree ○ Strongly Disagree

2. The people who drove *slowly and hesitatingly* deserve a fine

○ Strongly Agree ○ Agree ○ Neutral ○ Disagree ○ Strongly Disagree

3. I can tolerate the behaviour of the people who drove *fast and pushing*

○ Strongly Agree ○ Agree ○ Neutral ○ Disagree ○ Strongly Disagree

4. I can tolerate the behaviour of the people who drove *slowly and hesitatingly*

○ Strongly Agree ○ Agree ○ Neutral ○ Disagree ○ Strongly Disagree

5. I don't care why people drive *fast and pushing*; they just shouldn't do it

Strongly Agree Agree Neutral Disagree Strongly Disagree

6. I don't care why people drive *slowly and hesitatingly*; they just shouldn't do it

Strongly Agree Agree Neutral Disagree Strongly Disagree

7. It's okay with me if people drive *fast and pushing,* as long as they have good reasons for it

Strongly Agree Agree Neutral Disagree Strongly Disagree

8. It's okay with me if people drive *slowly and hesitatingly,* as long as they have good reasons for it

Strongly Agree Agree Neutral Disagree Strongly Disagree

9. I was able to see people who drove *fast and pushing* as decent citizens.

Strongly Agree Agree Neutral Disagree Strongly Disagree

10. I was able to see people who drove *slowly and hesitatingly* as decent citizens.

Strongly Agree Agree Neutral Disagree Strongly Disagree

11. It upsets me to see that people who drive *fast and pushing* are treated disrespectfully

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

12. It upsets me to see that people who drive *slowly and hesitatingly* are treated disrespectfully

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

13. I am not really interested in how people who drive *fast and pushing* feel

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

14. I am not really interested in how people who drive *slowly and hesitatingly* feel

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

15. The possible emergency situation of the people who drive *fast and pushing* does not influence me a great deal

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

16. The possible situation of the people who drive *slowly and hesitatingly* does not influence me a great deal

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

17. I would like to speak out when I see people who drive *fast and pushing*

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

18. I would like to speak out when I see people who drive *slowly and hesitatingly*

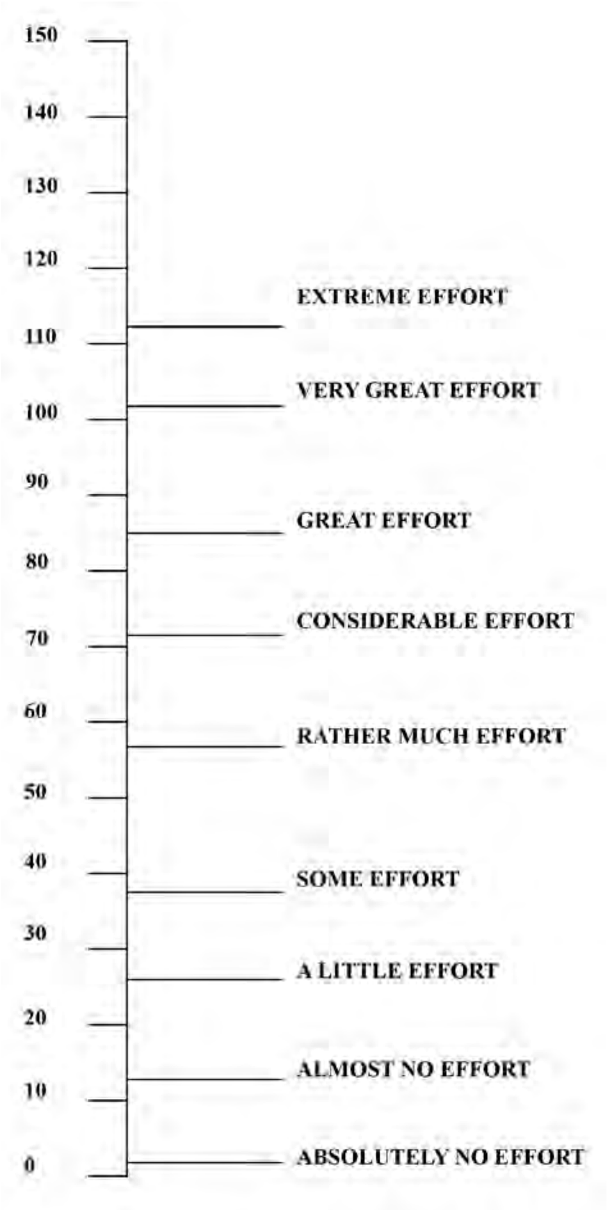
○ Strongly Agree ○ Agree ○ Neutral ○ Disagree ○ Strongly Disagree

19. After I see someone driving *fast and pushing,* I keep fighting with this person in my imagination

○ Strongly Agree ○ Agree ○ Neutral ○ Disagree ○ Strongly Disagree

20. After I see someone driving *slowly and hesitatingly*, I keep fighting with this person in my imagination

○ Strongly Agree ○ Agree ○ Neutral ○ Disagree ○ Strongly Disagree *c) Please indicate, by making the vertical axis below, how much effort it took for you to complete the task you've just finished.*



d) Please rate the experience of this journey

Pleasant	○	○	○	○	○	○	○	**Unpleasant**
Good	○	○	○	○	○	○	○	**Bad**
Aesthetic	○	○	○	○	○	○	○	**Unaesthetic**
Inviting	○	○	○	○	○	○	○	**Rejecting**
Attractive	○	○	○	○	○	○	○	**Unattractive**
Sympathetic	○	○	○	○	○	○	○	**Unsympathetic**
Motivating	○	○	○	○	○	○	○	**Discouraging**
Desirable	○	○	○	○	○	○	○	**Undesirable**

APPENDIX B: THE QUESTIONNAIRE APPLIED IN CHAPTER 7 OF MUSICHOUND

How you like the music played in the driving scenario?

a) Please answer the question based on your experience in the scenario

○	○	○	○	○	○	○	○	○	○	○

Very good Neutral Very bad

b) Please answer the following questions by using the scale below them

1. I don't feel related to other drivers.

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

2. I see myself as a loner while driving.

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

3. I feel disconnected from the drivers around me.

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

4. I feel understood by other drivers.

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

5. I see other drivers as friendly and approachable.

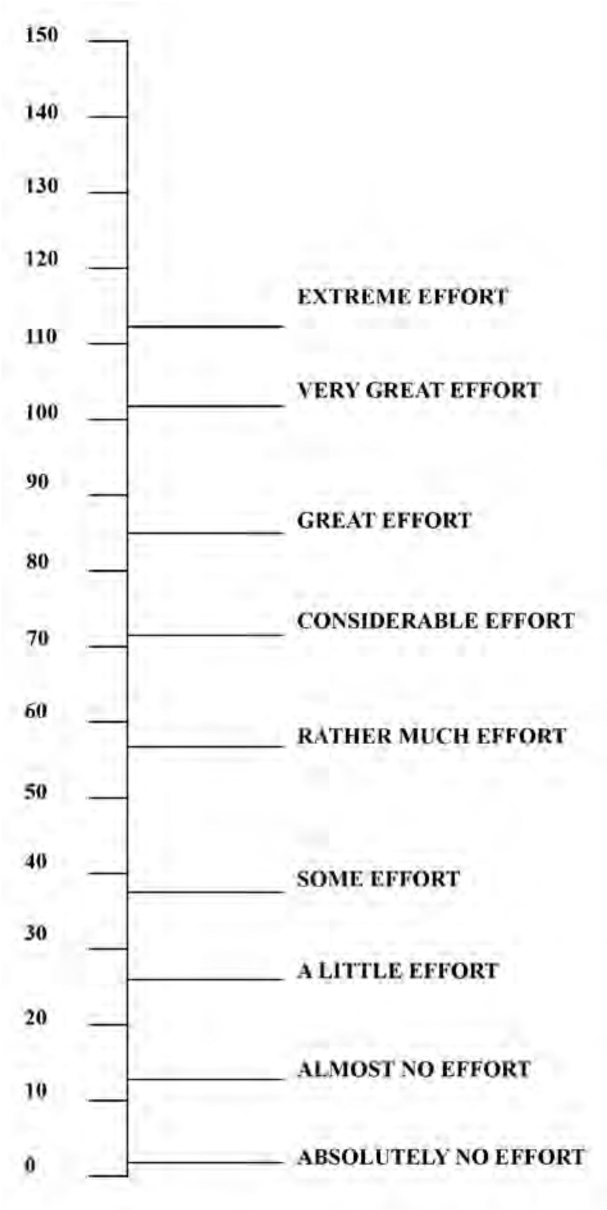
○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

6. I have little sense of togetherness with other drivers.

○	○	○	○	○
Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

c) Circle the picture that best describes your relationship with the other drivers around me (S = Self, C= other drivers).

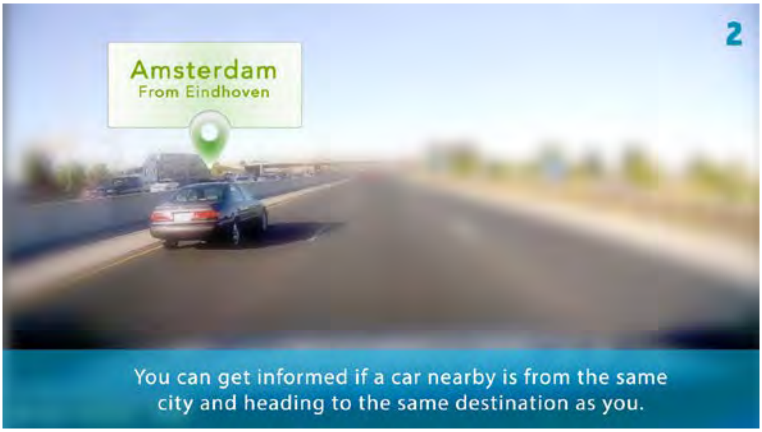
d) Please indicate, by making the vertical axis below, how much effort it took for you to complete the task you've just finished.

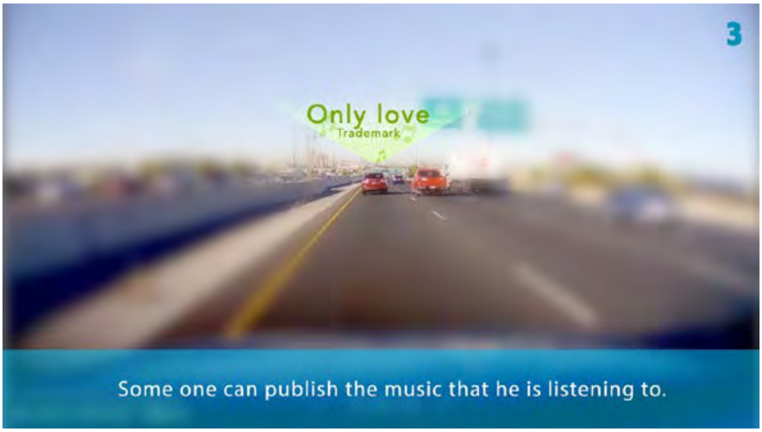


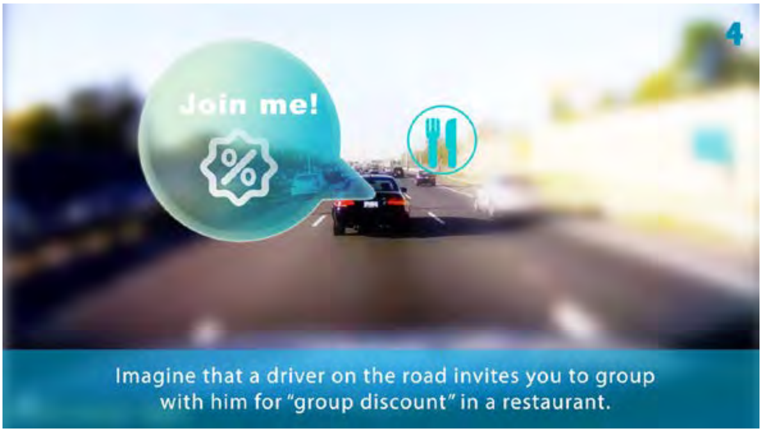
e) Please indicate, by making the vertical axis below, how much effort it took for you to complete the task you've just finished.

Pleasant	○	○	○	○	○	○	○ **Unpleasant**
Good	○	○	○	○	○	○	○ **Bad**
Aesthetic	○	○	○	○	○	○	○ **Unaesthetic**
Inviting	○	○	○	○	○	○	○ **Rejecting**
Attractive	○	○	○	○	○	○	○ **Unattractive**
Sympathetic	○	○	○	○	○	○	○ **Unsympathetic**
Motivating	○	○	○	○	○	○	○ **Discouraging**
Desirable	○	○	○	○	○	○	○ **Undesirable**

APPENDIX C: 30 NOVEL CONCEPTS IN CHAPTER 3

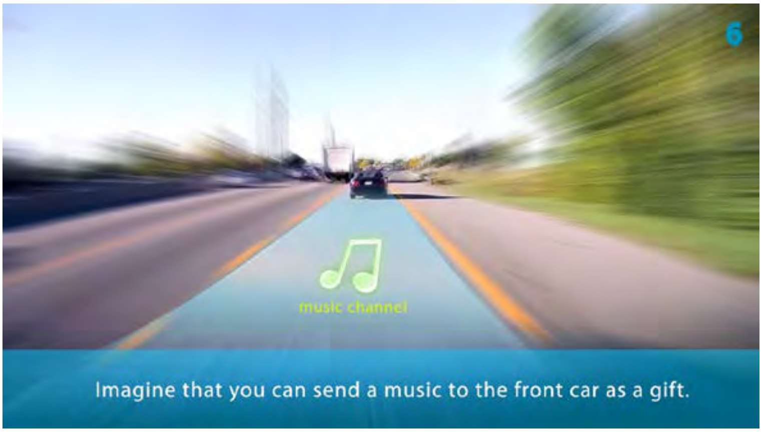






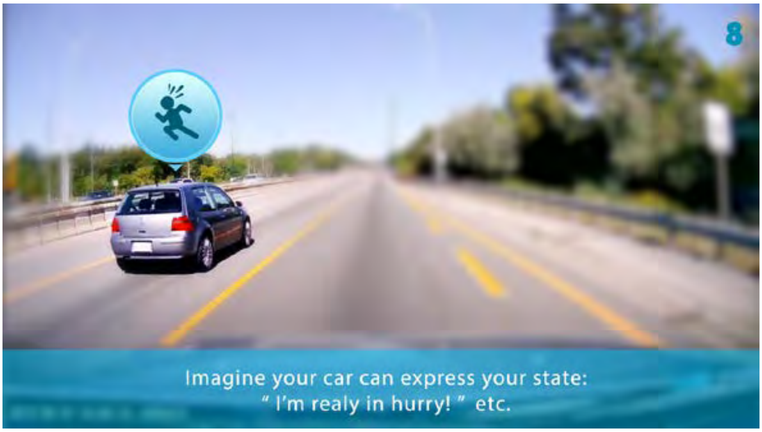
Imagine that a driver on the road invites you to group with him for "group discount" in a restaurant.

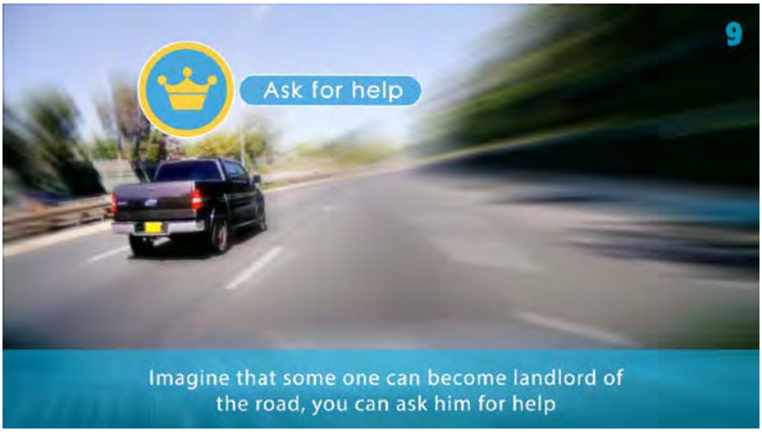
Imagine that some drivers can generate colorful "vitural shields" as decoration by augmented reality technology to show their personalities.



Imagine that you can send a music to the front car as a gift.

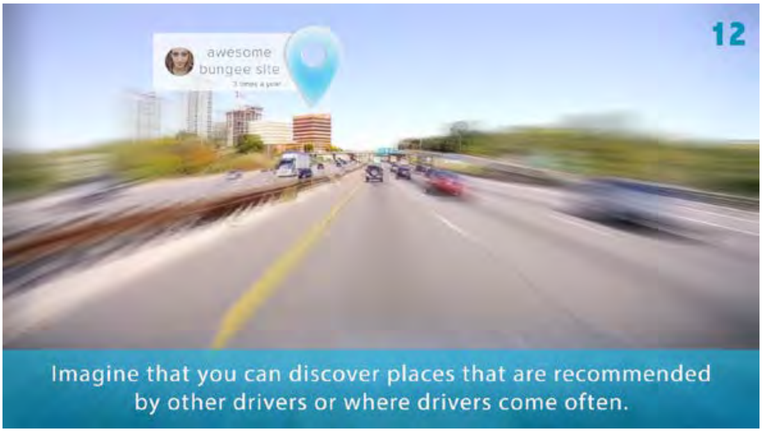

7
63
km/h
Imagine that your music volumes down once the car in
front of you suddenly break.

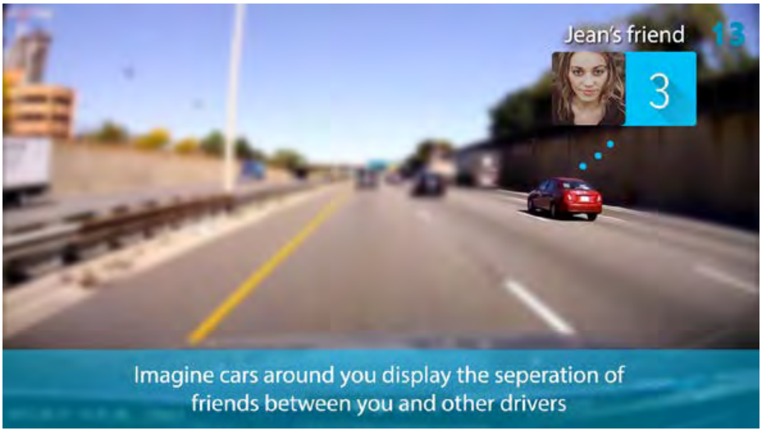

8
Imagine your car can express your state:
" I'm realy in hurry! " etc.


9
Ask for help
Imagine that some one can become landlord of
the road, you can ask him for help


10
Imagine that you spot a trendy car on the road, you can check its music genre or restaurants history it often visits.


11
ACC
Imagine that you can discover the car running near yours cruises its way through automatic cruise control, self-driving etc.


12
awesome bungee site
Imagine that you can discover places that are recommended by other drivers or where drivers come often.

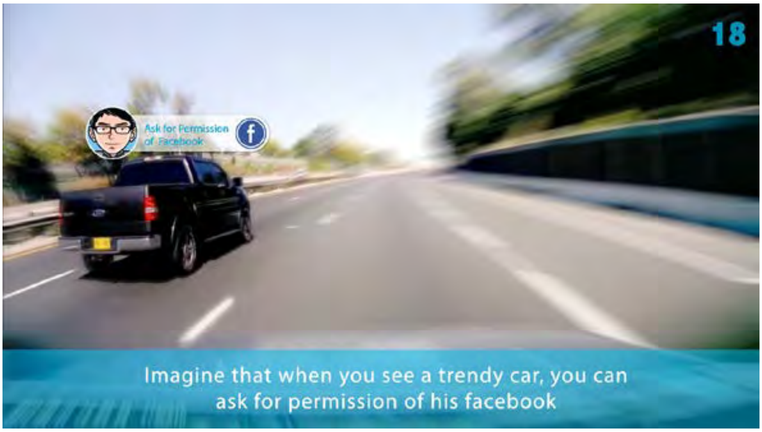

Jean's friend
13
3
Imagine cars around you display the seperation of
friends between you and other drivers

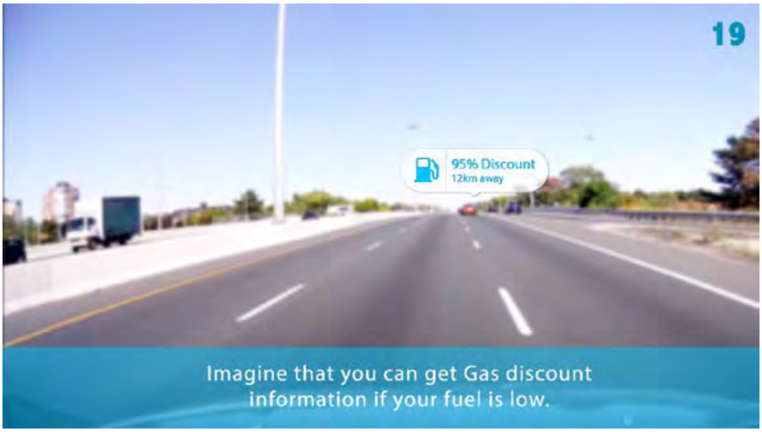

14
Facial expression of car to show the driver's mood:
tired,exhilarating, angry


15
driving record
Imagine that if someone give you the way
to pass, you can "like" his driving behavior.

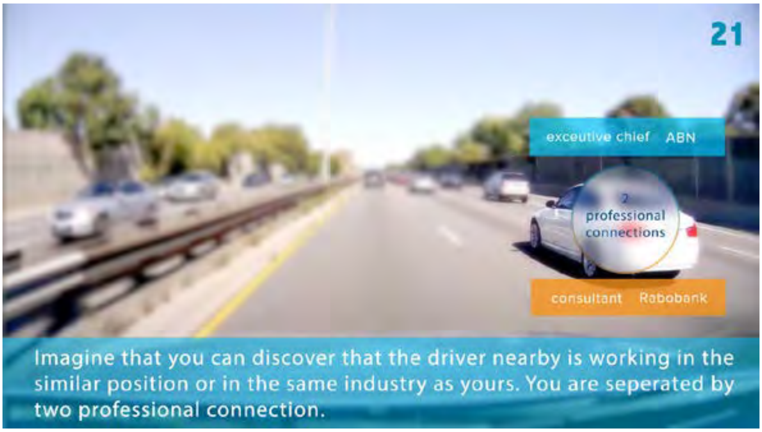

16
More space Please
Imagine that you can remind the behind car to keep distance from yours

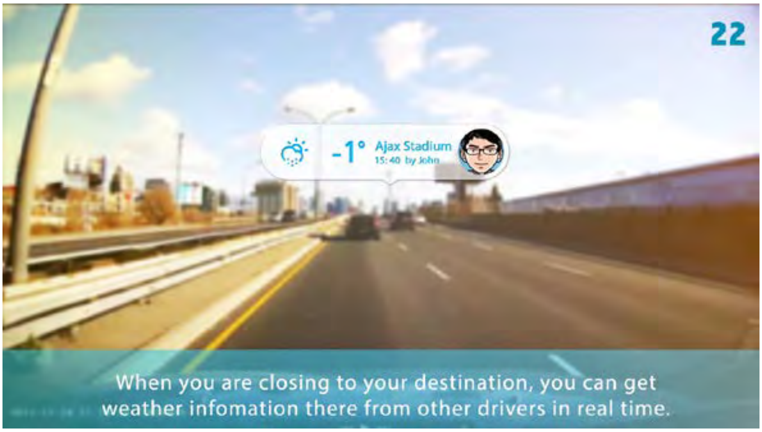

17
Imagine that your seat vibrates from left to right, it indicates that the car is going to overtake you from your rear of your left .


18
Ask for Permission of Facebook
Imagine that when you see a trendy car, you can ask for permission of his facebook


19
95% Discount
12km away
Imagine that you can get Gas discount
information if your fuel is low.

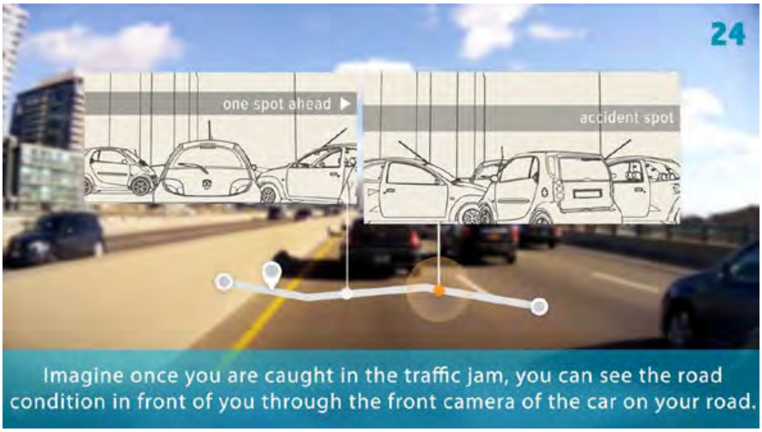

20
Advanced driver
Imagine that you can check the driving skill of
the driver whose car is in front of yours.


21
exceutive chief ABN
2
professional
connections
consultant Rabobank
Imagine that you can discover that the driver nearby is working in the
similar position or in the same industry as yours. You are seperated by
two professional connection.

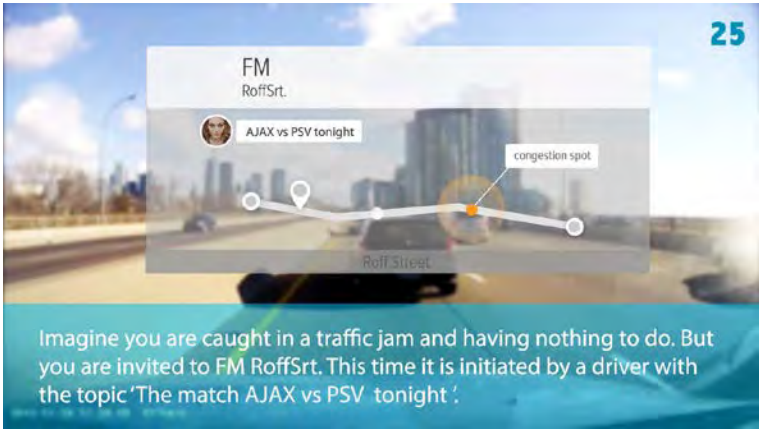


When you are closing to your destination, you can get weather infomation there from other drivers in real time.

Imagine that you and your friends will meet in a city, you can discuss the travel plan with your firends while driving.



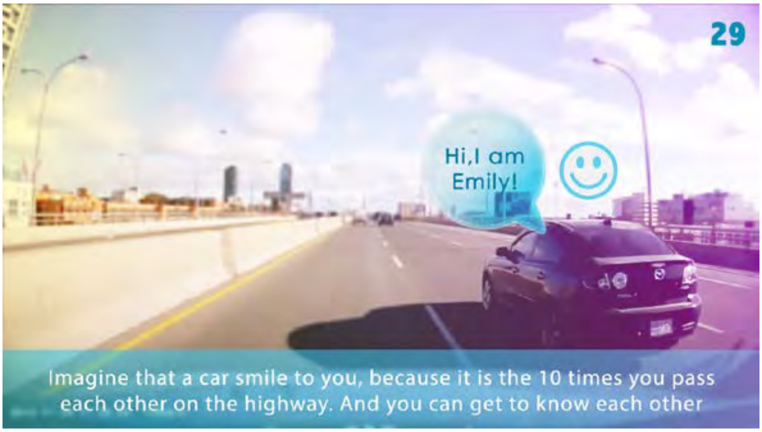
Imagine once you are caught in the traffic jam, you can see the road condition in front of you through the front camera of the car on your road.

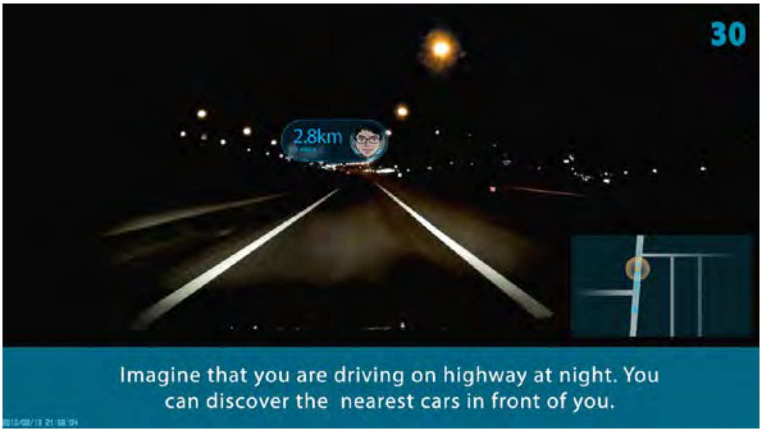

25
FM
RoffSrt.
AJAX vs PSV tonight
congestion spot
Roff Street
Imagine you are caught in a traffic jam and having nothing to do. But you are invited to FM RoffSrt. This time it is initiated by a driver with the topic 'The match AJAX vs PSV tonight'.


26
ask for priority on the side lane
you
Children in emergency
Imagine that a driver whose child is seized with a serious sickness asks for priority on the side lane


27
Fanally, the traffic jam is unimpeded!
Imagine when you are on the road, twitter messege of nearby drivers can be displayed.


28
PSV
Imagine that there is a platform for drivers to post some information on the road, and you can get filtered information which is relevant to you


29
Hi,I am Emily!
Imagine that a car smile to you, because it is the 10 times you pass each other on the highway. And you can get to know each other


30
2.8km
Imagine that you are driving on highway at night. You can discover the nearest cars in front of you.

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Summary

The road environment can be seen as a social situation: In each journey, we encounter other drivers and need to coordinate with them to share the infrastructure. A traditional physical communication method, such as car-body language, lights, horn and speed are the most frequently used means to exchange information, limiting both the range and the bandwidth of the connectivity. This situation may lead to two adverse effects: more conflict in sharing the road and social isolation while driving.

Nowadays, everywhere available connectivity, the broad penetration of social network services and the increasing utility of advanced human-machine interaction technology, provide new possibilities for enhancing the communication between drivers on the road, enabling social information to pass through the steel shell of the cars without the physical restriction. In this research, we generated, prototyped and evaluated multiple novel social applications as probes to investigate the research goal:

> *Designing different social-car applications to enrich the communication between drivers and positively influence driving behaviour and experience.*

Then two specific research questions were raised to address this goal: 1) Does digital augmented communication help to mitigate the conflicts in

sharing the road? 2) Does digitally augmented communication reduce the social isolation of the drivers?

To answer the research questions, I proposed a structured framework for better interpreting the forthcoming social network between drivers based on the previous research, and zoomed in our study on the *synchronous-nearby* communication. Then more than 30 novel concepts of social communication on the road, which were generated by brainstorming, were investigated through the co-constructing story telling method. According to the “Four-sides model”, four concepts were selected to probe the insight of exchanging different aspects of social information enhanced by digital augmentation.

Application *Likes and dislikes* enlarges the communication channel by enabling drivers to send and receive appreciation and disapproval. Another application *CarNote* enlarges the communication channel by providing explanation of people’s fast and slow driving behaviour. These concepts were elaborated, prototyped in a driving simulator and a user test was conducted. The result of experiments shows that drivers’ conflicts in sharing the road may be reduced by digital augmentation which enlarges the communication channel.

Two concepts, *iSticker* and *MusicHound* were raised to enhance the social closeness by presenting similarity information between drivers. The results of the simulator experiments show that information, which establishes social bonding by matching anonymous drivers’ similar interests, exerts a positive influence on social closeness and belongingness on the road. As a result, it is concluded that digital augmentation can reduce social isolation.

Generally, this study explores the possibilities of locative mobile social networks in the new frontier: connected road environment. The concepts, prototypes and experiments show the great potentialities of social interaction between drivers enhanced by social network in the future.

Publication List

Wang, C., Terken, J., & Hu, J. (2017, March). CarNote: Reducing Misunderstanding between Drivers by Digital Augmentation. *In Proceedings of the 22nd International Conference on Intelligent User Interfaces* (pp. 85-94). ACM.

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Curriculum Vitae

Chao Wang started his PhD research in the Industrial Design Department of Eindhoven University of Technology in 2013. His PhD research, Social Car, aims to enhance social communication between drivers. During this research, he developed distinguishing projects on improving social communication on the road. In order to realise his concepts and design, he used multiple means of interaction in both primary and peripheral way, including gestural, facial recognition and ambient lighting. These novel prototypes have been tested in a driving simulator as well as partly implemented in a real car. He published several papers in high-level conferences such as IUI, Auto-UI or AHFE, and got best paper award of AHFE 16', best poster award of Auto-UI 15' and best demo award of Auto-UI 17'. Furthermore, his research was featured by many famous media such as New Scientist, Engadget and Trouw.

In addition to his dissertation research, he also participated the development of the connected and autonomous driving vehicles, as part of A-team, a group that is supported by NXP, TNO, TU/e and Fontys. He designed and implemented a screen based HMI system to control the vehicle and an ambient lighting system on the dashboard to enhance drivers' situation awareness in the autonomous driving status. The autonomous driving vehicles were demonstrated in the 67th Frankfurt Auto Show, in Dutch Technology Week 17' and Dutch Design Week 17'.

Before starting his PhD project, he was a UX designer with two-year working experience in Shanghai Motor Group, which is the largest auto manufacturer in China. He was responsible for several projects of HMI and related components design. Currently, all projects have been commercialized and got quite positive feedback from market and media.

The combined background of industry and academia brings him solid knowledge on design, coding, prototyping, ability to convert ideas into applications/ products, a can-do attitude and profound insights into the new trends of technology.

This is a serious research, indeed