CarNote: Reducing Misunderstanding between Drivers by Digital Augmentation

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ABSTRACT
The road environment can be seen as a social situation: Drivers need to coordinate with each other to share the infrastructure. In addition to the driving behaviour itself, lights, horn and speed are the most frequently used means to exchange information, limiting both the range and the bandwidth of the connectivity and leading to misunderstanding and conflict. With everywhere available connectivity and the broad penetration of social network services, the relationship between drivers on the road may gain more transparency, enabling social information to pass through the steel shell of the cars and giving opportunities to reduce misunderstanding and strengthen empathy. In this study, we present "CarNote", a concept that aims to reduce misunderstanding and conflict between drivers by showing their emergency driving status 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.

Author Keywords
Connected car; driving violations; computer-mediated communication; social computing.

ACM Classification Keywords
H.4.m [Information Systems Applications]: Miscellaneous; H.5.2 [Information Systems Applications]: User Interfaces-user-centered design

INTRODUCTION
The way people agree on how to share the road space could be understood as a form of negotiation [2]. However, the current communication methods seem insufficient for expressing the driver's intention and providing the context of their behavior, which may lead to misunderstanding and trigger aggressive driving behavior. The advent of everywhere available connectivity and the broad penetration of social network services provide opportunities for changing this situation [3], enabling social information to pass through the steel shell of cars and giving opportunities to reduce misunderstanding and strengthen empathy in order to create more harmonious road environment.

"CarNote" emerged from a study by Wang et al [4] in which thirty different "social car" ideas were discussed with more than twenty people (Fig.1). 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.

Figure 1. The concept "CarNote".

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 [14] any driving behavior 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 [5]. 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 [6]. It was also reported by Parker et al that, over and above other variables, intentional aggressive driving behavior makes a significant contribution to involvement in traffic accidents [28].

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Understanding the causes of aggressive driving is essential for effective intervention. Therefore, a variety of explanatory models of aggressive driving have been proposed. Brewer [8] 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 [29] 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 [5], a model was proposed (Fig.2). In this model, all aggressive driving behavior 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 implicitly 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 on the interpretation of "trigger".

Empathy and 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 showed that there is a significant relation between empathy and forgiveness [1] 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 [9]. The empathiser sees or hears about the situation of the empathee and imagines this situation from his own perspective [11]. For example, when one supermarket shopper blocks another's path with their trolley this is unlikely to result in a violent confrontation because the person's facial expression will usually convey the fact that he or she did not intend to do it and is apologetic for having done so [12].

However, as regards the communication between drivers, when the design of cars depersonalizes other drivers [10] and the bandwidth of communication is limited, the reason behind the behavior and emotional state would not be transferred 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. "Every silly act of driving could be interpreted by an angry driver as aggressive and insulting and thus provoke an aggressive response" [13]. For example, when overtaken by another fast driver, instead of thinking of another driver as a mother on her way to take her sick children to 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" are easily developed into aggressive reactions.

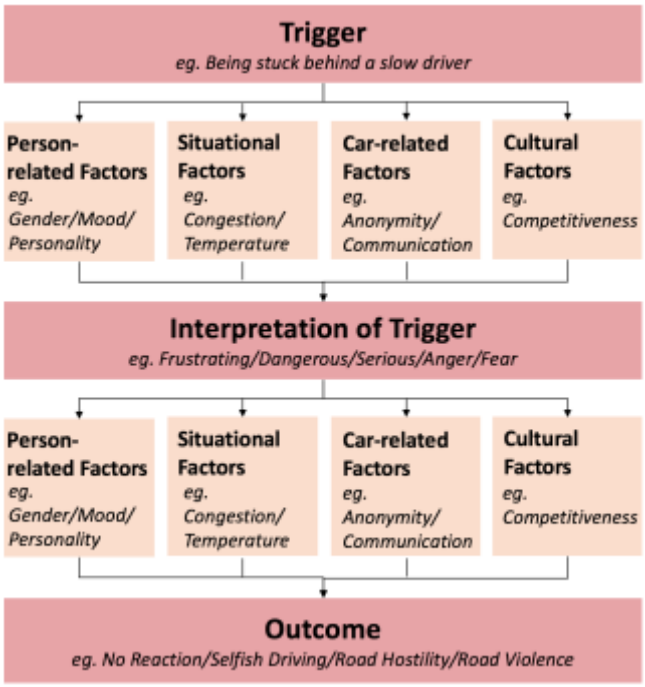

Figure 2. Causal model suggested by the drugs and crime prevention committee of the state of Victoria, Australia.

RELATED WORKS

Mitigating misunderstanding of "trigger event" by connectivity between drivers

Many attempts were made for mitigating 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 Renge has dubbed "roadway interpersonal communication" [14], for the purpose of transferring more social context to reduce misunderstanding on the road.

There also 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 [5]. It was discovered, however, that motorists found these mechanisms difficult to

use and so the campaign ceased. At the 2001 Tokyo Motor Show [16], Toyota displayed a car capable of warning other drivers of the driver's mood by the color 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 behavior of road users is traced by sensors, evaluated by systems and stored in the cloud.

Figure 3. Lexus LF-FC concept car enable driver to send pre-set message by gesture, such as "After you" and "Thanks", to nearby drivers.

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 [15], which enables the driver to send a pre-set message such as "After you" to nearby drivers by gesture (Fig. 3). Schroeter 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 [17]. An experiment in a driving simulator showed that their approach has the potential to improve social interactions between drivers, allowing clearer collective decision making between road users and reducing the incidence of antisocial behavior in 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.

APPLICATION

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.

Concept and rationale

In a study of Wang et al, 30 concepts for enhancing social communication between drivers were generated by brainstorming session [4]. One of them, which is described in the following scenario, was called "CarNote" and received high acceptance:

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 in 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 [11]: affective and cognitive. The affective component is seen as an immediate emotional response of the empathiser to the affective state of the empathee [18]. The cognitive component refers to the understanding by the observer of the other person's feeling. When another driver's "in a hurry to the airport" information is displayed on people's augmented reality windshield, it provides the explanation of their fast driving behavior as well as the anxious emotion state, which may evoke people's memory of the same experience.

Figure 4. 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. People may tend to cherish the authority of the usage. More importantly, it

enhances the reliability of the "hurry" status, which may contribute to the empathy.

Design, prototype and apparatus

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 (Fig. 4).

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 (Fig. 5):

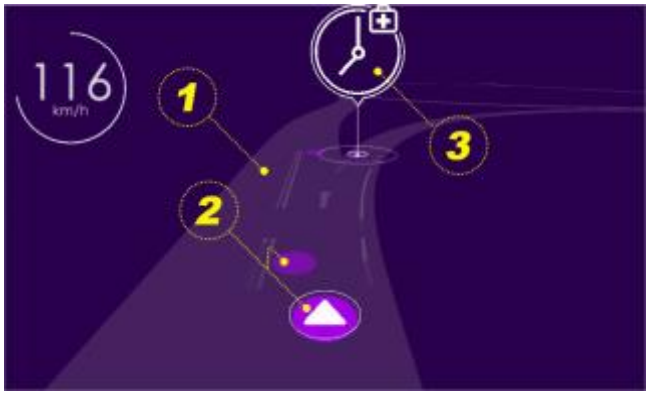

Figure 5: User interface design. 1) Geography layer; 2) Vehicle layer; 3) Notification layer

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 in special status (Fig. 6) and visual effect for their emergency situation.

Figure 6. 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".

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 emergency car to draw the drivers' attention. (Fig. 7)

Figure 7. Participants matched the sign in the interface to the car in the simulated scenario.

EVALUATION

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. 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.

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) [19] 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) [1] 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.

To measure the *angry rumination* of the participants, the Anger Rumination Scale (ARS) [20] 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 combined 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 [21]. 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".

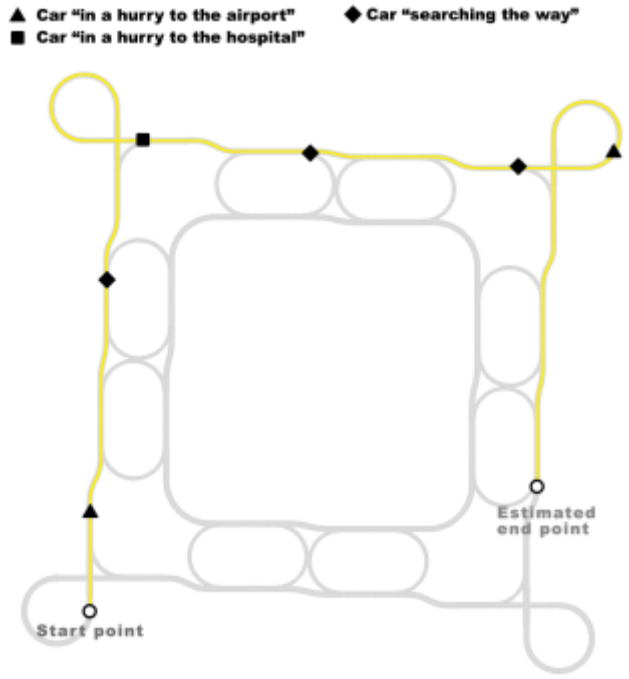

Figure 8. Locations which six cars appeared on the map.

To measure the appeal of the driving situation, we used a semantic differential [22], which was constructed by Hassenzahl et al [23] 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 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 experiment setting. Furthermore, in 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".

Scenario

A highway scenario that included curves, viaducts, entrance ramps and exit ramps, along with a high density of traffic 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 (Fig. 8): Three drivers drove at 15% over the speed and overtook the car in front of them that drove 5% slower. As a result, they had a higher probability of executing overtaking behavior. Three drivers drove slowly at 60 km/h on the middle lane near merge out ramps of the highway.

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 two slowly driving cars.

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.

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.

TEQ scale

Independent t-test was conducted to compare the empathy level of the two groups. 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 significant difference between empathy to slow driver in Groups 1 (Mean = 2.834, SD = 0.700) and Group 2 (Mean = 2.332, SD = 0.488), t (26) = 2.198, p = 0.37, r = 0.396.

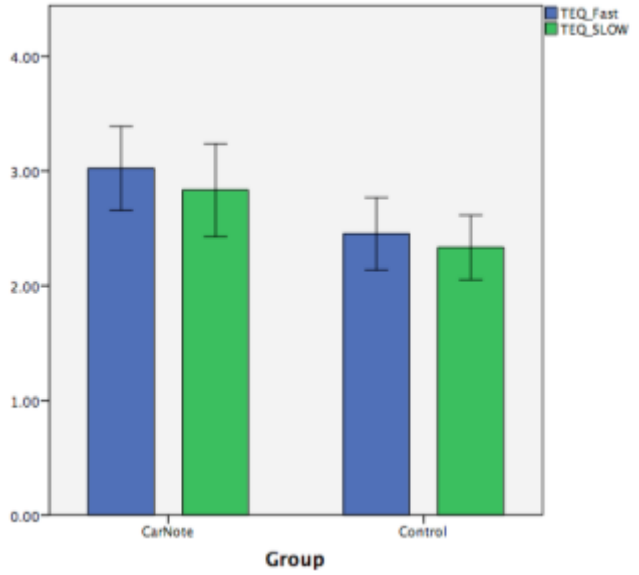

Figure 9 The result of TEQ (ranges from 1-5).

HFS scale

Based on the Independent t-test, participants in the scenarios where they could see the emergency sign felt significantly higher forgiveness than the participants in control group, both to the fast drivers and slow drivers on the road (for fast drivers: t (26) = 2.144, p = 0.042, r = 0.388, the Mean of group 1 was 3.200, SD was 0.618, Mean of group 2 was 2.700; for slow drivers: t (26) = 2.525, p = 0.018, r = 0.444, the Mean of group 1 was 2.957, SD was 0.666; the Mean of group 2 was 2.286, SD = 0.739).

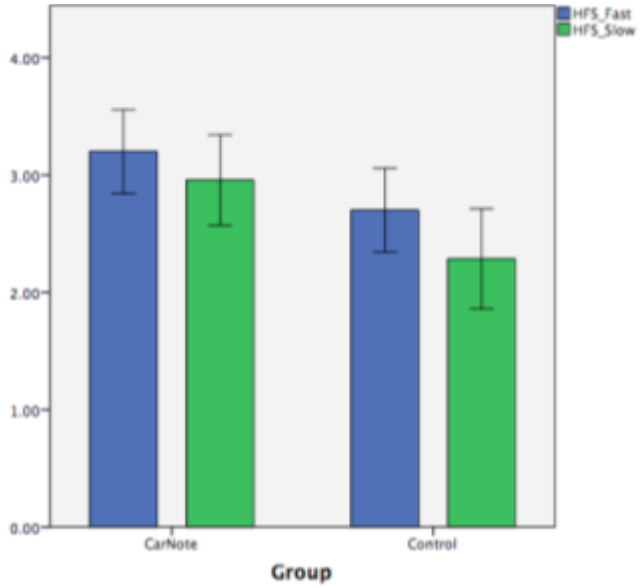

Figure 10. The result of HFS (ranges from 1-5).

ARS

Based on the Independent t-test results, there are no significant differences of Anger Rumination between participants in 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) and slow drivers (Group 1: Mean = 3.191, SD = 0.694; Group 2: Mean = 2.964, SD = 1.046).

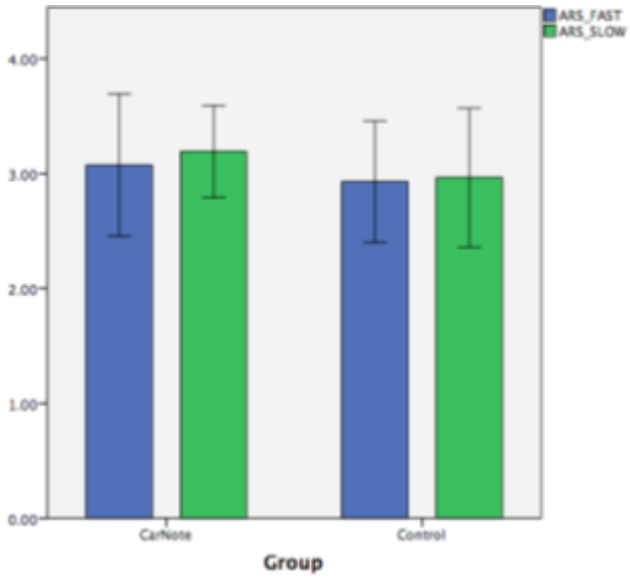

Figure 11. The result of ARS (ranges from 1-5).

Mental effort

As regards the mental effort of participants, which measured by the RSME scale, there is no significant difference between the two groups based on the Mann-Whitney U Test. The median mental effort of the group where participants could get music was 40.00, compared with the control group whose mean was 30.00.

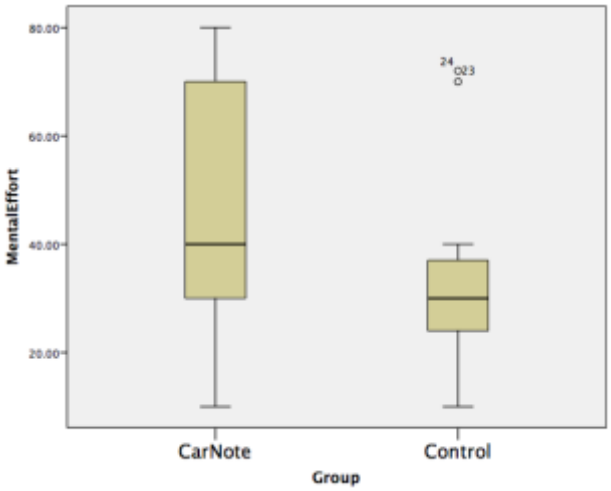

Figure 12. The result of RSME (ranges from 0-120).

Appeal

This questionnaire provides insight into the appeal of this application. Based on the Mann-Whitney U Test, there is no significant difference between the result of 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).

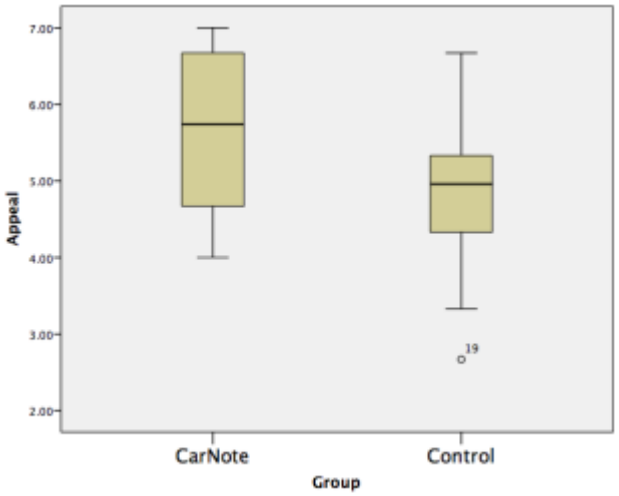

Figure 13. The result of Appeal questionnaire (ranges from 1-7).

QUALITATIVE RESEARCH

In order to gain structured insights from our study, we transcribed and analyzed the interview data by qualitative content analysis [24]. In this section, we report on the results of in total 141 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 behavior.

Acceptance

53 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*.

Figure 14: Words cloud of users' description of CarNote.

Description

Sixteen quotes from fourteen participants showed people's general impression of this application. Almost all of the quotes (27 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) (Fig. 14).

"I think it's really innovative, I could fully accept this idea." (Participant 2)

Positive factors

Fifteen quotes from six participants revealed factors that positively influenced people's attitude towards this application. Eight quotes from four participants mentioned that the CarNote enhanced safety because it enabled them to know "the purpose of other people". Seven quotes from 3 participants said they would reduce misunderstanding on the road if they knew the reason for others' behavior. Two participants stated that they can benefit from this application if they were also in an emergency situation. 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" (Participant 12)

"I may feel better if there is a sign, it feels like he said 'sorry' to you" (Participant 6)

Negative factors

Five 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 behavior. 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." (Participant 3)

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 behavior of the cars with virtual signs, however, the attitude towards fast drivers are quite distinct.

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" (Participant 6)

"… especially in a hurry to the hospital, I am sure that I will give him the way." (Participant 7)

However, there were two participants who stated that hurry to the airport is not an excuse to drive aggressively, "each driver should obey the traffic rules".

"It's questionable…although he is in a hurry, he can't drive over the speed limit, right? Why didn't they get up earlier?" (Participant 8)

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 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 globe picture." (Participant 11)

"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." (Participant 13)

Distraction

43 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

16 quotes from 14 participants described the general opinion of distraction. Nine participants thought CarNote did not distract on their driving task. Five participants confirmed that they felt a little distraction.

Nowadays, navigator software is widely installed on various devices such as smart phone, digital instrument or screen in the console. Eight participants said they put no effort to get the information from the interface because it was quite like their navigation system.

"No (distraction), not really. In my case, I could feel like using my navigation system. It's quite easy to get the information." (Participant 14)

"You have to use the GPS anyway. When you looking at the map and speed, you will see the information too." (Participant 7)

Mapping

Twelve quotes from ten participants mentioned about 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 the 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." (Participant 5)

"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." (Participant 1)

Information

15 quotes from 6 participants were about the content and quality of information they got. Seven quotes from 5 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 glance while driving and sometimes he "ignored" them.

"The icon is well designed, very clear." (Participant 13)

One participant thought to show 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." (Participant 10)

The "ripple" animation provides warning information that there is an emergency car 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 very advance… from some distance, if I know the car approaching which is in a hurry, I can make the way in very advance for him."

CONCLUSION

In this study, we investigated how drivers feel about showing surrounding drivers emergency 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. The quantitative results suggested that the people showed more empathy and forgiveness with the help of CarNote, while there are no differences between the anger rumination. Furthermore, the qualitative research results show that participants' attitude towards fast drivers and slow drivers are 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 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 behavior. 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. [9] 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 automatically responding with a smile and feeling happy when you see somebody smiles at you [25]. 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 behavior. If a hurry 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 that in 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.

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 a number of limitations to the research. Firstly, participants' driving behavior and emotional status may be biased by the limitations of the driving simulator. The performance of maneuvering 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. Thirdly, each driving session only lasted 10 minutes, therefore this study was not able to investigate participants' attitude towards this application in long term. Fourthly, 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 behavior 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 [26] or Airbnb [27]. 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. These will be taken up in future research.

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