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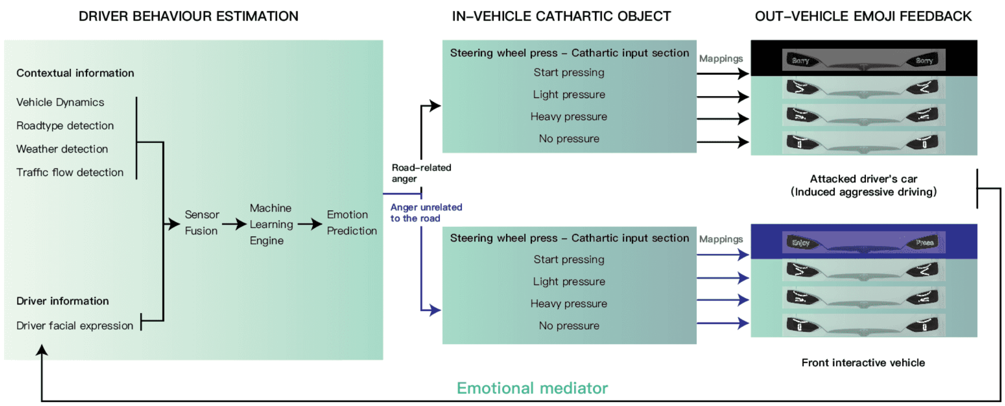

Figure 1: User-friendly affective system framework to leverage aggressive driving behavior.

ABSTRACT

Aggressive driving behavior has been proven to be one of the major contributors to road accidents. Traditional solutions to leverage aggressive driving behavior still have some obvious shortcomings such as low user experience and unsatisfactory effectiveness. This article explores user-friendly design method for intervening aggressive driving behavior based on human-centered motivation theory such as persuasive technology. We proposed an interactively affective system based on design ethnography and persuasive technology that offered drivers an emotional mediator and allowed them to express their feelings in a natural way that does not affect traffic. We validated our design and system in a driving simulating environment with 16 participants, results showed that our system could promote drivers emotional state effectively. Our system have broad application prospect such as traffic safety, driver health, intelligent cockpit human-vehicle interaction.

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CCS CONCEPTS

• **Human-centered computing** → **Interface design prototyping**.

KEYWORDS

Human-vehicle interaction · Persuasive design · Aggressive driving behavior · Cathartic theory

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1 INTRODUCTION

Globally, road-traffic accidents have become one of the most-serious problems endangering public-health worldwide while approximately 1.3 million people die in road-traffic accidents each year[27]. Road-traffic injuries, not only have dire consequences in terms of death, injury and psychological trauma[16], but also place a heavy burden on families and national economies. Some studies suggest that road-traffic injuries would become the third-most common cause of death by 2020 if effective interventions are not implemented[17]. A great deal of research on road safety has emerged over the past few decades addressing road safety issues. Aggressive driving behavior has received a lot of attention as one of the most important risk factors of traffic accidents[40] [44]. National Center for Statistics and Analysis has estimated that 27% of traffic fatalities involve aggressive driving behavior, such as speeding (13.5%), yielding (7%) and unsafe lane changes (7.5%).

In order to prevent aggressive driving behavior, various measures have been developed by society. These include high visibility enforcement (HVE) programs such as smart speed-cameras that automatically transfer violations to the police and track drivers' aggressive behavior to raise their insurance premiums. However, these interventions are mainly rooted in external factors, such as rule coercion and material rewards, which not conform with basic human need for freedom[6]. In short, aggressive driving behavior is a serious problem that must be addressed while current interventions are not very effective or user-friendly. This suggests an urgent need for innovative solutions thus form our research motivation of work.

In this paper, we proposed a novel user-friendly affective system to leverage aggressive driving behavior. Our system was designed under motivation theory by analyzing aggressive driving behavior. Generally, motivation could be divided into extrinsic ones and intrinsic ones. For aggressive driving behavior, which was also defined as "a syndrome of instrumental behavior driven by frustration", current solutions always failed to consider drivers' motivations especially the intrinsic ones. Therefore, one of the effect methods to address aggressive driving behavior was to set up a rational external intervention to induce drivers' mood swing. According to that, we conducted a 14-day-long experimental with two cameras to record drivers' natural driving behavior from their daily commutes. Results showed an important insight that aggressive driving behavior could be regarded as the drivers' response to their own negative emotion, which fits the philosophy of cathartic theory. Thus, we dug out that the most effective way to address aggressive driving behavior was to allow drivers to express their aggression in a way that does not affect other drivers. Therefore, we adopted persuasive design technology into our system to influence drivers' intentions voluntarily. Persuasive technology had been evolved into several frameworks to support designers with automotive systems design.

Our system consisted of three parts, drivers' behavior estimation, in-vehicle cathartic object and out-vehicle emoji feedback (see Figure 1). 1) Drivers' behavior estimation based on computer vision to judge drivers' level of aggressiveness; 2) In-vehicle cathartic object developed as an interactive haptic user interface on the steer wheel for drivers to relieve their feelings; 3) Out-vehicle emoji feedback generating corresponding emojis on the rear LEDs of relevant vehicles. We evaluated the efficiency and experience of our system in a driving simulation environment under scenarios that may induce aggressive driving behavior considering safety issues in real road. Results indicated that our system can effectively reduce users' aggressive driving tendencies with user-friendly experience. The contributions of our study are:

- An innovative design methodology based on motivation technology to address aggressive driving behavior issues.
- Design and implementation of an effective user-friendly system to interactively reduce drivers' aggressive behavior.
- Theoretical and practical design insights and reflection on human-vehicle interaction.

2 RELATED WORK

2.1 Aggressive driving behavior: definition, models and causes

Although different definitions have emerged over the years, but the current mainstream understanding is in line with Shinar's statement that 'aggressive driving behavior' is, 'a syndrome of frustration-driven instrumental behaviors, manifested by: 1. indifference or disturbance to other drivers (flashing headlights, honking at others), and 2. deliberate dangerous driving (obstructing the path of others, running red lights, etc.) in order to conserve time at the expenses of others'[42]. 'Instrumental aggression' refers to all actions taken by the aggressor in order to overcome frustrating obstacles. Thus, going quickly around corners is not considered aggressive driving, as this situation does not include frustrating obstacles. In addition to frustrating obstacles, the judgment of other drivers affected by the behavior is also crucial. If a driver believes that his behavior does not constitute aggression, while other drivers judge it as rude and annoying, then behavior is also subordinate to aggressive driving. Aggressive driving is interpreted in the text as frustration-driven instrumental aggression and is distinct from similar driving-behaviors such as road rage and dangerous driving. This type of aggression is present in 'normal' people who occasionally engage in aggressive behavior while driving a car.

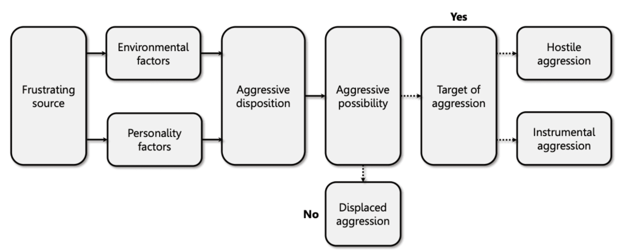

Figure 2: Multi-factor model of aggressive driving according to Shinar (1998)[42].

In addition to defining aggressive driving behavior, there has been a lot of research to figure out how this behavior arises and develops. The multi-factor model of aggressive driving developed by Shinar (1998) (see Figure 2) systematically describes this process[42]. A central part of the model is that situational-based frustration hinders the driver from accomplishing their prime driving-goal of moving forward in a smooth and unimpeded manner. The source of frustration may be the presence of other road users, events or an objects. It is clear that dispositional elements, including environmental elements and personality elements, control and influence the driver's propensity to be aggressive.

If one individual is not physically, mentally or situational carrying out the aggressive behavior due to moral constraints or law requirements, the aggression may be carried out elsewhere at another time which is known as 'displaced aggression'. If the driver is conditioned and capable of aggression, they will choose a target and enact it. The target may be a perceived source of frustration or a random and completely-unrelated other person. Shinar (1998) argued that aggressive driving could be ameliorated in two ways:

direct impact on behavior through traffic regulations or indirect impact on behavior through prevention, manipulation or elimination of frustration.

2.2 Motivation theory to reduce aggressive driving behavior

Motivation theory proposes that all human behavior is driven by motivation so aggressive driving behavior can be explored by research into motivation theory. Usually people are driven by two types of motivations when they engage in behavior: one is extrinsic motivation of doing activities to achieve various goal, and the other one is intrinsic motivation of conducting activity being meaningful to themselves[36]. Thus, when people are engaged in an activity for living income, to escape punishment or to obey social rules, they are extrinsically motivated.

There is a large amount of research on intrinsic and extrinsic motivation. Many studies have found that intrinsic motivation might lead to better conceptual learning, more creativity, greater cognitive flexibility and higher levels of happiness than extrinsic motivation[39]. As a result, there has been a great deal of interest in learning about the conditions that reinforce or decrease intrinsic motivation. That is, although intrinsic motivation is innate in human characters, external events can assist people with maintaining intrinsic motivation, or reducing it. For instance, research has shown that other external events such as commands, supervision, penalties, and negative feedback might lead to a decrease in intrinsic motivation[45].

Although external stimuli may change motivation and behavior to some extent, people would tend to lost interest and fail to persevere in the process. If an activity requires creativity and forethought, their performance may be poorer. Conversely, external factors that taking into account people's feelings and deliver positive feedback are found to be well motivated and may result in better performance. Ryan & Deci explained this phenomenon in terms of both competence and autonomy[39]. Specifically, positive feedback facilitates the satisfaction of the basic need for competence, while negative feedback frustrates this need. Similarly, command, surveillance and punishment are seen by people as controllers of their behavior and hinder the development of their autonomy. In contrast, choice and approval are seen as supporting their autonomy. Thus when both needs are met in an activity, people are highly intrinsically motivated to behave accordingly.

2.3 Current solutions of leveraging driving aggressive behavior: case, problem and gap

Based on motivation theory, an in-depth analysis of current solutions to address aggressive driving behavior are carried out. The most-common approach is to use enforcement interventions such as speed cameras to limit speeding behavior. This approach controls the driver's need for autonomy and might introduce pressure to them. Thus the driver may not perform the appropriate behavior due to the frustration of their sense of autonomy and make safe-driving less intrinsically motivated. This is also the reason why the majority of drivers will unconsciously increase their speed after passing a speed-measuring device[48]. There are also schemes to predict aggressive driving behavior by constructing driver models and alerting drivers when they are about to engage in such behavior[47]. These would also affect the drivers' autonomy. There are also insurance schemes that record data on driving-behavior and charge lower fees to drivers who drive sensibly. However, the external incentives used to stimulate drivers to make changes are generally not effective, because the autonomy associated with intrinsically-motivated behavior can be undermined by the provision of external rewards.

The above solutions only focus on extrinsically-motivated changes and ignore the adverse effects of intrinsic motivation, making performance less than optimal. Therefore, changing the intrinsic motivation of drivers is a more reasonable approach. Shinar suggested to remove the frustration at the source[42]. Johnson suggested to reduce aggressive driving behavior by alerting drivers of possible congestion ahead of time in order to alleviate drivers' frustration[18]. The results show that these methods were effective to some extent, as it meant some drivers adjusted their mindset to prepare for possible delays, however the methods were only effective for drivers with high levels of anger, while increasing aggression for drivers with low anger-levels. It also showed that designing user-friendly driving environments would reduce drivers' frustration. Adjusting drivers' interactions with the environment could subconsciously change their intrinsic motivation in order to reduce the frequency of aggressive driving.

For the purposes of our study, aggressive driving behavior is defined by shinar as 'a syndrome of instrumental behavior driven by frustration'[42]. Based on this definition, she constructed a multifactorial model of aggressive driving that response to a source of frustration in a driving situation. Frustration arises when other people or things get in the way of the driver's goals. This source of frustration is characterized by a negative emotional-experience caused by the interference[4] [11]. There are two main approaches to addressing aggressive driving, one is to reduce the driver's extrinsic motivation to drive aggressively through coercion, and the other one is to enhance the intrinsic motivation of the driver by providing preparations for frustration. Both of the two approaches have drawbacks: the former struggling to balance the need for intrinsic- and extrinsic-motivation, and the latter achieving less than satisfactory results. This lead to the inspiration and motivation our study to set up a rational external intervention to induce drivers' mood swing.

3 PILOT USER STUDY

3.1 Data collection - Video ethnography

This study focused on data collected in a natural driving state that was not constrained by a strict experimental design. It captured accurate driving-information by systematically extracting data, such as video and audio, directly from the participants' real driving-lives. Each driver's own vehicle was instrumented (as unobtrusively as possible) and they were asked to continue driving their vehicle as usual. Data was collected throughout the period of use. The aim was to provide a record of natural behaviour that was as unaffected as possible by the measurement process. Naturalistic driving-research has recently received a great deal of attention and has been applied to a number of areas, such as driving subtask studies, driver distraction, and the influence of driver emotion on driver behaviour, with good results. Most of the data processing has however, been coded by researchers based on their own understanding of the data collected, without the involvement of the participants[26]. This study collected data on naturalistic driving, and also invited the participants to undertake semi-structured interviews in order to code the factors associated with aggressive driving-behaviour. In particular, drivers' emotions (outbursts of anger, anger removal etc.) would be assessed by the drivers themselves, which would solve the problem of users not having strong emotional-expressions when coded by the researchers, as well as hopefully leading to more-accurate data-analysis.

The investigation began on 20 June 2021 in Leshan, Sichuan Province, Mainland China, with a fortnight experimental period in which two cameras were set up to record naturalistic driving-data from drivers' daily commutes. A wide-angle camera was positioned behind the driver to record their behaviour, and another to record their front view from the vehicle, as shown in Figure 3,4. Participants were allowed to temporarily deactivate the camera recording system by pressing a button on the camera. The data obtained from the video was supplemented by some information from an external database. The information of traffic flow, weather, roadtype, vehicle dynamics were identified by GPS.

3.2 Participants

It has been shown that aggressive driving-behaviour manifests itself differently for different types of drivers[21], and therefore to develop a widely applicable study it is important to explore different groups of people to find commonalities between them. Our study focused on age, gender and driving experience which are the three main factors influencing driving behaviour and we consciously took this into account when recruiting participants. The experiment therefore recruited three different types of drivers as participants (1 female and 2 males) between the ages of 27 and 45 years old (M=33.3, SD=8.3) volunteered for this experiment:

- Middle-aged men with extensive driving experience.
- Young men with less driving experience.
- Young women who had just obtained their driving licenses.

3.3 Procedure

Participants' cars were fitted with cameras that record their driving activities. The video mainly captured the daily commute of drivers over a two-week period. It was processed according to the definition of aggressive driving-behaviour adopted in this project, and selected video clips of aggressive driving-behaviour, were used as material for the subsequent interviews. User interviews were conducted in-person in Mainland China. It is for the three participants whose driving behaviour was recorded on video above. First, participants were invited to review video clips (processed video data) that contained the complete process of how their aggressive driving occurred, from the normal driving state, to the event triggering, to the display of the aggressive driving behaviour, and finally the return to normal driving. The aim was to capture comprehensive information related to the aggressive driving-behaviour, as well as to have a record of the previous situation to help participants better recall their state at the time, and to obtain user feedback that was closer to the real driving-state. The next step was to ask the interviewees to describe how they felt at the time and why they acted in the way that they did to some of the events and behaviours presented in the video. By gaining a deeper insight into the aggressive driving-behaviour, the best way to intervene could be explored. Interviews were audio recorded.

3.4 Results and discussion

A total of 43 incidents of aggressive driving-behaviours were observed during the two weeks of the experiment. Of these, 24 were interactions with motor-vehicle road-users (e.g. vehicles cutting in front of them), 11 were due to road conditions (e.g. traffic congestion), 4 were due to traffic lights (e.g. prolonged red traffic-lights) and drivers' own triggers (e.g. disorientation).

Figure 3: Three common scenarios that induce aggressive driving.

The above showed that there are a large number of triggers for aggressive driving-behaviour in modern urban-commuting in Leshan, Sichuan Province, Mainland China, mainly in the form of events that impeded the road users' goal of moving forward. In most cases, interactions with motorised-vehicle drivers caused aggressive driving-behaviour in participants, and within this there was potentially a vicious circle at play: the illegal and illicit behaviour of other road-users could trigger previous negative-feelings and existing aggressive-tendencies in drivers. In other words, if a driver failed to control their aggressive-driving tendencies and exhibited aggressive behaviour, the driver became a trigger for other road-users' aggression; so the attacker was the victim and the victim was the attacker.

Aggressive driving-behaviour took the form of five main manifestations: verbal abuse, loud honking, banging on the steering wheel, accelerating and changing direction (As shown below). These five manifestations were not usually seen individually, but in combination. The interviewees stated that they did this to express their frustration (anger) at the irrational driving-behaviour of other road users, as a way of venting their frustration at having their goal of moving forward blocked by others. This is because, for reasons of traffic safety, a driver must sacrifice their own interests (temporarily stop moving forward) when faced with a conflict on the road. Thus, after experiencing a road event in which their interests have been violated, they developed negative-emotions (anger), and needed to vent by demonstrating to others through some of the above-mentioned means. If the other driver then made concessions as a result of the aggressive expression, this was determined by the interviewees to be a good way to alleviate the original anger and led to a positive feeling. Conversely, if nothing was done, the driver's anger was exacerbated and the level of aggression increased, for example from verbal abuse inside the car to rolling down the window and shouting at the driver. According to the interviewees, the aforementioned anger did not last long, especially if the driver received 'positive feedback' from the previous aggressive driving-behaviour, such as the other driver raising their hand in apology, then the angered driver could quickly move on from the previous angry state and behave positively. Even if the driver did not profit, they could forget the previous unpleasantness relatively-quickly. It was self-reported that the anger that triggers aggressive driving is therefore short-lived, acting only on the immediate event and having little effect on later driving activities.

Figure 4: The five main expressions of aggressive driving behaviour.

The results of the interviews suggested that aggressive driving could be seen as a driver's behaviour in response to their own negative-emotion of anger. Anger arose as a result of others' non-compliant use of the road, causing the frustration of interviewees' driving-goals (compromised interests), and therefore aggressive-driving manoeuvres were adopted to alleviate angry emotions. This fits with psychological research suggesting that expressions of aggression lead to emotional release, which reduces tension and makes people feel better[3] [46]. It has also been shown that angry people seem to feel better when they attack, and some seem to engage in aggression because they are seeking this emotional benefit. Based on the idea of cathartic theory, expressions of aggression can have a positive emotional-outcome for the initiator of the attack, intervening to dissipate the negative emotions previously generated. Thus, perhaps the most effective way to address aggressive driving-behaviour as an issue is to allow drivers to express aggression in a way that does not affect other road users, cutting off the pathway to the reproduction of aggressive driving-behaviour in other users, as shown in Figure 5. And during the user study it was found that the verbal behaviour of the drivers when expressing their dissatisfaction was usually expressed as: 'This car is so annoying and takes up my lane', ' This car was so rude it blocked my route'. The above aggressiveness towards the vehicle may be understood to mean that the forward frustration is caused by the actions of the driver of the vehicle in front of him during driving, but in the opinion of the forward frustrated driver, the vehicle in front is a more intuitive factor in causing the frustration. The vehicle in front therefore appears to be the culprit for the driver's frustrated progress, which can be seen as a proxy for the driver. According to psychological theory, catharsis manifests itself as an act of destruction of an object with the aim of directing strong emotions into a purposeful action[14]. There are two main types of cathartic action: acting directly on the source of the anger (for example, punching an opponent); and symbolic acts of displacement, such as symbolically scratching the eyes out of a photograph of the source of anger or inserting pins in a doll representing a personal enemy)[14]. This inspired the creation of an agent of the source of the driver's anger, as a cathartic object for the driver in the in-car environment.

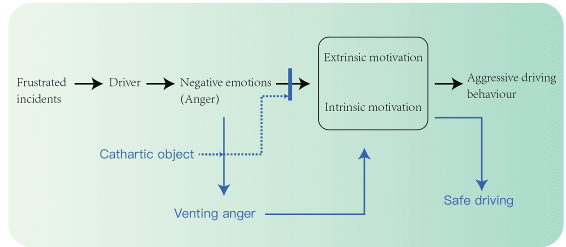

Figure 5: Aggressive driving motivation generation and intervention.

In addition to this, an interesting phenomenon was found: during driver calls there seemed to be a higher tolerance for aggressive-driving incidents and a lower propensity to drive aggressively. This can be interpreted as the call task taking the driver out of the driving task for a brief period of time, so the driver's focus on moving forward is reduced and the anger triggered by the obstructing event is then relatively low, leading to a lower propensity to drive aggressively.

4 SYSTEM DESIGN CONCEPT

4.1 Persuasive design

Trying to reduce aggressive driving behavior requires a shift in the drivers' emotions (frustration) and behavior (aggression). Whenever an attempt is made to change another person's behavior, thinking or emotions we are on the topic of influence. Persuasion is characterised by influencing the intentions of others to change voluntarily, and is a form of influence. As such, persuasion is clearly distinguished from behavioral-change resulting from deception, rule coercion or prize incentives[43] [13]. In the public and scientific contexts, persuasion attempts are primarily focused on behaviors that results in social problems. For instance, when the health domain launches anti-obesity campaigns and green organisations speak up for the environment, persuasion 'happens'[43]. In the field of human-computer interaction, users can be persuaded through the computer as a medium of communication, by the computers as a bridge to other users, and by interactive systems, which refers to Human-computer persuasion[15]. Increasingly, interactive systems are being designed to change users' feelings or behaviors for the better, in areas such as fitness and exercise[25], healthcare[32] or sustainable development. These systems are all manifestations of persuasion techniques, defined as, "computerised software or information systems designed to reinforce, change or shape attitudes or behavior or both without the use of coercion or deception"[29]. Although psychosocial methods have been employed to study the persuasiveness of systems, they cannot be directly applied to human-computer interaction. As a result, new frameworks and models of persuasion have been developed. Two of the most common ones are: Fogg's work, summarised as Captology[13], and Oinas-Kukkonen & Harjumaa's[30] Persuasive Systems Design model(PSDM).

Under Fogg's persuasive technology, "The persuasive computer is a technique of interaction that attempts to alter behavior or attitudes in a certain way". Based on this definition, Fogg coined the term, “captology” for, “the research of the computer as the persuasive technology”. Captology draws on the idea of the media equation hypothesis in the field of media psychology, which assumes that users treat other new media, such as computers and television, as if they were human beings[35]. In addition, captology follows fundamental principals of social psychology, such as expressing compliments, promoting a sense of belonging and developing personality traits[2]. Captology was the pioneer of persuasive technology, but its design bias and lack of engagement with core users led to shortcomings.

For this reason a persuasive system-design model (PSDM) was later developed[31]. Here, persuasive systems are defined as, "computerised software or information systems designed to reinforce, change or shape emotions or behavior, or both without the use of coercion or deception"[29]. Compared to Captology, PSDM enables a more systematic understanding, design and evaluation of persuasive techniques, and it also specifies what the final system should have and how it should function. PSDM depicts the research on persuasive techniques into a three-step process: (i) understanding the key issues of the persuasive system context, (ii) analysing the persuasive environment, and (iii) designing the requirements of the system to be developed based on the results of the analysis[31]. PSDM is a generic approach. It requires an adapted approach if it is to be applied to persuasive situations with special requirements.

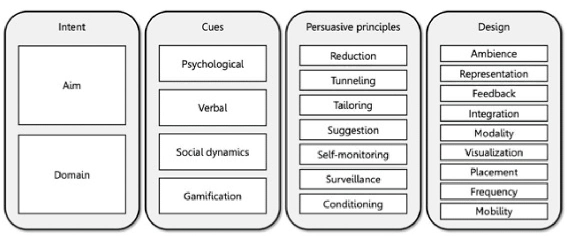

Figure 6: Persuasive interface design framework in the automotive domain according to Paraschivoiu et al. (2019)[33].

The Persuasive Interface Design Framework for the Automotive Domain, developed based on PSDM, is a framework for supporting designers in designing automotive systems[33]. Its core elements are as follows:

- Defining the intent of the system: The intent is determined by the domain of application and the purpose and of the system. In the automotive industry, the purpose of persuasion can be to perform safe driving, ecological driving or other driving-related domains of attitude or behavior.
- Identifying relevant cues: Cues are system characteristics used to cause desired changes. They can be divided into four features: social dynamics, gamification, psychological cues, and verbal cues. Social dynamics are mainly considered to trigger competition or cooperation between users. Gamification refers to the use of elements used in game design[10]. Mental cues are differentiated as to whether they are perceived and processed consciously or unconsciously by the driver. Verbal cues refer to the use of written- and spoken-language.
- Persuasive principles: PIDAF adapts Fogg’s seven principles of persuasiveness, (i) reduction (reducing complex activities to simple steps), (ii) tunneling (leading through a sequence of actions), (iii) customisation (providing relevant and personalised information), (iv) advising (providing advice on appropriate behavior), (v) self-monitoring (providing information on performance and progress), (vi) monitoring (others monitoring the individual’s performance and progress), and (vii) moderation (using positive reinforcement).
- Specifying the final design of the system: Environment (peripheral or focal), integration (additional or enhanced to existing interfaces), mode (visual, tactile and/or auditory), location (inside or outside the vehicle) and mobility (mobile or fixed) are options that relate to the physical configuration of the potential interface. In contrast, representation (concrete or metaphorical), feedback (immediate or delayed), visualisation (discrete or continuous) and frequency (in action, as a summary, or prior) are options that could help to determine the content of the final system.

4.2 Design ethnography

Having clarified the intent of the system: to mitigate aggressive driving behavior, the next step was to find appropriate cues and incorporate appropriate persuasive principles to guide the development of the final product. This required an in-depth study of drivers exhibiting aggressive driving behavior, in order to gain insight into the needs of the driver at that time. To this end, design ethnography was introduced: a fusion of a human-centred design approach and ethnography, which Milton & Rodger described as, “a flowing process involving the gathering, explanation and demonstration of data that has its roots in the discipline of cultural and social anthropology”[37]. Ethnographic studies normally include, “fieldwork in everyday life, studying the whole to provide a more complete context of activity, a rich description of people, environments and interactions from an objective perspective, and a bias towards understanding activity from the informant’s point of view”[41]. This is useful for developing new systems. The methods encompassed under design ethnography are always evolving and expanding. Often, elaborate observations, semi-structured interviews and document analyses are included. These methods were used in the current research.

5 SYSTEM IMPLEMENTATION

5.1 Design inspiration

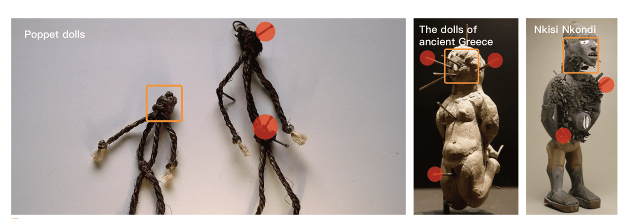

Figure 7: Characteristics of cathartic objects.

According to psychological theory, catharsis has been shown to release negative feelings through interactions with destructive objects[24]. The forms of catharsis interaction are mainly reflected in being manipulated and destroyed, so interactive affective system should allow for physical direct-manipulation. There is also previous research exploring the design of ancient Japanese Dogu statues for use in designing interactions with agents, and concluding that detailed facial design is more important than the body[19].

Based on the above inspriation and combined the specific context of use of the driving situation and persuasion theory, a prototype was developed in order to modify the driver's frustration and reduce the driver's motivation to drive aggressively. The prototype consisted of three parts, as shown in Figure 8.

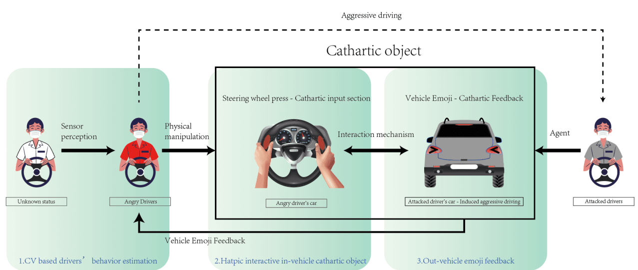

Figure 8: Prototype system diagram.

5.2 CV based drivers' behavior estimation

In driving situations where the driver's attention is focused on road-related driving activities, the human-vehicle interaction can no longer be initiated by a person as in traditional HCI, but by the vehicle. The vehicle uses intelligent sensing technology to obtain the driver's status and turn on the interactive affective system. Algorithms for facial expression recognition are now commercially and widely available to measure drivers' emotions and stress[1]. Thus using computer vision to determine if a driver is angry. In addition to this, contextual information is also collected through GPS sensors, such as traffic flow, weather detection, etc. weather, road type and vehicle dynamics to determine why drivers are angry. In order to create an appropriate channel of interaction between the driver and the vehicle for different anger situations. This step is used as a trigger for the interactive affective system. At the same time, eye-tracking devices are used to capture vehicles on the road where the driver's attention is, to identify vehicles on the road that are causing driver anger, and to build a bridge between the two based on v2v communication.

5.3 Hatpic interactive in-vehicle cathartic object

Pilot user study results show that pressing the horn on the steering wheel is the most prominent manifestation of aggressive driving behaviour. Therefore, we have set up a pressing area on the steering wheel as the cathartic input for the angry driver to destroy through physical manipulation. The physical manipulation of the catharsis was mainly communicated by tactile channels, so this part was most important for the choice of materials and design of contact positions. The aim of this project was to allow the driver to cathartically express their anger by pressing on the prototype to deform it, so the materials of popular stress-relief toys currently on the market were used as a reference. Participants were invited to assess the usefulness of commercially-available materials for catharsis. The results show that the user needs to be able to create a more pronounced deformation when cathartically expressing their emotions, so that they feel that they are causing damage; while at the same time the material has to give them a reverse force, so that they feel some resistance. In addition to this, the steering wheel manipulation must not be affected.

For this reason, considering all factors the airbag area was chosen. This is because the airbag area can be adjusted by adjusting the amount of air pressure to adjust the feel of press. When in normal driving conditions, the air pressure can be increased so that this part is not deformed and is perfectly integrated into the steering wheel. When the driver's need for catharsis is detected, the internal air-pressure could be reduced so that this area can be deformed by pressure and turned into a cathartic object. The position of the device is shown in the red area of the steering wheel in Figure 8. The reason for this is ergonomic, was that it makes it easier for the thumb to apply force and would not interfere with the driver's steering. In terms of shape, it was designed to fit the shape of the thumb. Overall, the pressing area can be seen as a substitute for pressing the horn, i.e. retaining the physical manipulation of catharsis but effectively hindering outward aggression. And the tactile interaction does not interfere with the driver's vision, which helps in ensuring driving safety.

5.4 Out-vehicle emoji feedback

The most important thing is to give positive feedback to the person who is venting. Research has shown that the use of emotion in cars can provide better interfaces[28] and enable new driver-car interactions[51]. Facial expressions, known as non-verbal communication are crucial in driver-car interactions[12][20] as it can help both parties to predict each other's intentions and awareness well[50]. Recently, researchers have studied external interfaces designed for vehicle operators and other road-users (e.g., pedestrians)[9] . In addition, a study has proposed the concept of "AEIC" (Augmented Emoji in Car), which enhances the interaction between the driver and the rear seat passengers by providing feedback to the driver on the passenger's current emotional state through Emoji[8]. From the above it is clear that current emojis are already being used in the field of human-vehicle interaction, but to transfer them to cars and make them effective in conveying appropriate emotions, new emojis need to be designed and adapted. Through the use of emoji, the prototype was designed to make the car seem like a creature with feelings, so it could act as an agent of the attacked driver and to convey appropriate emotions as a cathartic feedback. Therefore, a few of the current mainstream emoji versions, namely Apple, Google and Microsoft, were analysed (see Figure 9a). The transmission of emoji messages often relies heavily on the design of the faces within the emoji, with the eyes and mouth being the most emotionally communicative. Arguably, the areas where the car interacts directly with the drivers of other vehicles visually reflect the human face. The human-like eye design of the lights, with the smooth lines of the front of the grille subtly resembling the car's 'big mouth', gives the vehicle a human demeanour as well, which makes the emoji a reasonable option to migrate to car use. The shape of the car is fixed from the moment the car is manufactured and only the LED lights can be adjusted, so this is where emoji could be used. In addition, there is a current trend for smart cars to move in this direction (cars interacting with pedestrians via lights).

According to the analysis of the interviews, the final emotional feedback expected from the driver was apologetic and should also change accordingly with the strength of the driver's catharsis (the intensity of the press). The participants were asked to select the emoji that they felt would best express an apology from the emoji library. The results are shown in Figure 9b. Two key elements were extracted from the apology emoji: the bent eyebrows and the aggrieved eyes. From this, the researcher designed the car light emoji to make the car seem to be apologising. Three different sets of expressions were created (see Figure 9c), and from left to right the level of apology increases.

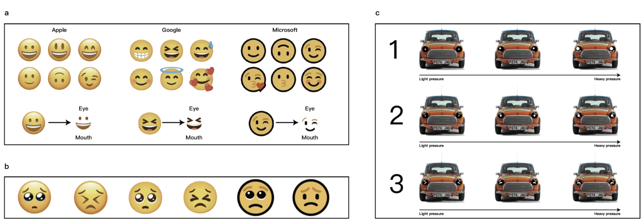

Figure 9: Emoji design for the interactive affective system

The prototype satisfies two elements of a cathartic object as an act of displacement: direct physical manipulation (destruction), and a face design (following the vehicle-emoji feedback). However, it was not possible to make the user visually and tactilely focus at the same time, as in the case of the voodoo doll for catharsis mentioned above. This posed the challenge of how to link the two separate devices, so that the driver saw them as a whole and as agents of the source of anger. To do this, an interaction mechanism was designed to link the two separated objects.

5.5 Prototype implementation

The Persuasive Design Framework for the Automotive Domain was used to guide the development of cathartic objects, and was partially adapted to the actual situation:

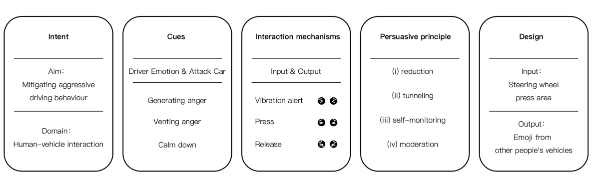

Figure 10: Persuasive theory to guide the development of cathartic objects.

- **Intent:** the purpose and domain of the system development is currently defined. Automotive Human-Machine Interaction: intervening in drivers' aggressive driving behaviour.
- **Cues:** the first step was to use computer emotion-recognition and GPS sensors to collect information on the driver's emotions and road conditions, in order determine whether the driver has an aggressive-driving tendency and the target of the attack (e.g. a car cutting in front), and thus establish an interactive channel between the two vehicles.
- **Interaction mechanism:** when the system determines that the driver is about to drive aggressively, the cathartic press-area set into the steering wheel would activate and emit appropriate vibrational stimuli as a mapping of the non-compliant driving-behavior of the vehicle in front of them, directing the driver to disrupt this area (cathartic physical manipulation). The vibration alert was chosen because it is a common alert method used in current vehicles so is more familiar to drivers and does not interfere with their vision, allowing them to focus on the vehicle they wish to 'attack' ahead. At this point the driver would see the emoji on the lights of the vehicle in front of them, be linked to his physical manipulation of the steering wheel. Emoji is the feedback (output) to the cathartic manipulation of the steering wheel, which anthropomorphises the car (an emotionless object) for the driver. The emoji would then dynamically change with the driver's level of catharsis need (pressing force) in order to build a link between the two separate devices (of physical manipulation and expression feedback), forming a complete cathartic object. When an angry driver is detected pressing the button on the steering wheel, instead of the emoji appearing directly in the lights, a text saying, "Sorry" appeared first. This is because emojis can be misunderstood when used to communicate information, and the use of text was deemed a reasonable good solution to this problem. The presence of, "sorry" sets the tone for the subsequent interaction, which aims to have the attacked vehicle apologise to the angry driver. This also created an apologetic context for the upcoming emoji that would appears in front of the angry driver, allowing the emoji to send the right information to mitigate the driver's anger. The vehicle will display the word "Enjoy press" when the driver's anger is likely to come from non-driving related activities, such as work stress. The decision of which mechanism the device activates will depend on the vehicle's intelligent sensing technology. Furthermore, the anger of the angry driver would not presented to the driver of the interacting vehicle or to other users of the road. The angry driver would quietly interacts with the object of their anger through the device and adjust their state. All other road-users would see would be a vehicle 'apologising' for the angry driver, which may spread of polite behavior and perhaps subliminally promote polite-driving.
- **Persuasive principles:** the system incorporates four categories of persuasive principles: (i) reduction (reducing complex activities to simple pressing operations that do not interfere with normal driving), (ii) tunneling (designing a series of mechanisms for guidance), (iii) self-monitoring (responding to one's level of catharsis through emoji), and (iv) modulation (emoji changes dynamically in response to pressing force). The two persuasive principles: Advice and Supervision were removed because these two external factors would

frustrate driver autonomy and reduce intrinsic-motivation. (This study was aiming to address aggressive behavior from the inside out, and not through external pressure, like traffic enforcement).
- **Design:** the two carriers are the steering wheel and the vehicle emoji for the driver's anger catharsis.

The prototype was designed to act as an agent for the 'attacked' driver, interacting with the angry driver and allowing them to express their anger. Within the process, persuasive design was engaged, in order to reduce the intrinsic- and extrinsic-motivations for the aggressive driving behaviour. The interaction with the prototype would only presented only to the angry driver, as feedback to the interaction, so would not affect other users on the road.

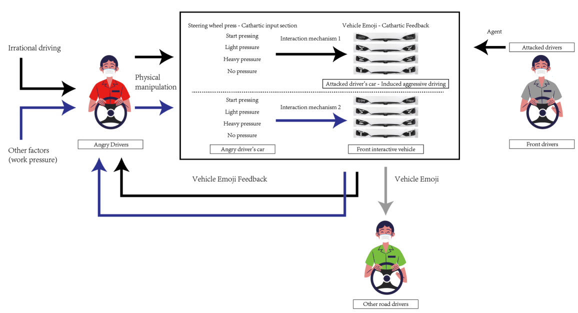

Figure 11: Mechanisms for operating the In-vehicle catharsis object.

6 SYSTEM VALIDATION

Regarding the use cathartic theory to mitigate negative emotion in driving situation, we expected that the user-friendly interactive affective system would reduce driver anger caused by the frustration of moving forward. Previous research has shown the benefits of catharsis in improving people's moods[7] and sense of fairness[23]. And the success of catharsis depends on the identity of the person toward whom the catharsis is addressed and the response received—catharsis was found to be beneficial when the receiver is either the offender, or a neutral third-party listener[34]. The expressive physical motion of a robot could serve as an appropriate response—it has the potential to either symbolically represent the offender, or to serve as a third-party listener, both of which have been shown to be beneficial as part of cathartic interaction[34]. In-Vehicle Catharsis Object views the vehicle causing the forward frustration as the offender and using that vehicle emoji as the appropriate response to the anger driver in the rear, which could influence driver's anger state.

In the 2D valence-arousal emotion space[38], angry be viewed as high-Arousal and negative-valence. Therefore we can measure the driver angry from changes in arousal and value. We propose the following two hypotheses:

H1: In-Vehicle Catharsis Object reduces the level of angry arousal perceived by driver during frustrating driving events.

H2: In-Vehicle Catharsis Object change the angry driver perceptions about the emotional valence of frustrating driving events.

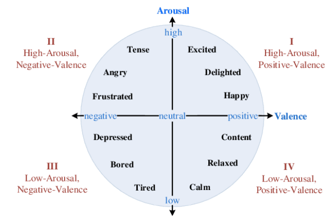

Figure 12: The 2D valence-arousal emotion space[38].

6.1 User study

We recruited 16 Chinese participants for this experiment (7 male, 9 female). Participants were randomly divided into two groups, one group (8 people) participating in the condition with In-Vehicle Catharsis Object and one group participating in the condition without that prototype. Their mean age was 23.52 (SD = 4.04) years. None of the participants had any background information about the experiment before joining the study.

Figure 13: Interaction with the Emoji in the simulated driving environment.

We evaluated the efficacy of In-Vehicle Catharsis Object by using simulation experiments. The reason for choosing a scripted scenario instead of testing the prototype in a more naturalistic setting was to control the scenarios that induce aggressive driving behaviour. Based on previous research, we selected the two most frequent driving scenarios (overtaking, traffic congestion) that tend to induce aggressive driving behaviour to carry out simulated driving experiments. The participants sit in front of a computer monitor which displays a first-person driving scenario, holding a steering wheel with the press device to control the vehicle. And participants were told to push on the press device when they felt angry during the driving process. Afterwards, participants start to steer the vehicle forward and after a period of familiarisation with the driving simulation, which is for participants to immerse themselves in the driving scenario, will encounter pre-determined scenarios that induce aggressive driving behaviour. The press area (cathartic input) on the steering wheel are the Arduino FSR402 to detect the participant's pressure and transmit the pressure data to the computer to control the emoji changes, thus simulating the interaction between the driver and the cathartic object in the car. The entire experiment was recorded. And participants were asked to indicate the intended level of emotional arousal and the intended level of emotional valence by selecting one of the five manikins (5-point scale), respectively, in the Self-Assessment Manikin (SAM) test developed by Bradley and Lang[5]. Participants were interviewed at the end of the session.

6.2 Results and Discussion

To test our hypotheses and explore our research questions, we measured the driver's anger state by calculating the average arousal and emotion scores for each scenario that induced aggressive driving behaviour.

Table 1: The median arousal and valence evaluations

	driver emotional arousal	driver emotional valence
In-Vehicle Catharsis Object (overtaking)	3.75	1.37
Without In-Vehicle Catharsis Object (overtaking)	4.25	1.12
P value (overtaking)	0.037	0.621
In-Vehicle Catharsis Object (traffic congestion)	3.87	1.75
Without In-Vehicle Catharsis Object (traffic congestion)	4.12	1.50
P value (traffic congestion)	0.024	0.237

Our first hypothesis concerned on whether the In-Vehicle Catharsis Object reduces the level of angry arousal perceived by driver during frustrating driving events. Results from a ANOVA showed that a significant main effect for In-Vehicle Catharsis Object on the mean angry arousal score. In both cases (overtaking, traffic congestion), the drivers' angry arousal is reduced to some extent. In overtaking situation, p=0.037, with In-vehicle catharsis object (M = 3.75, SD = 1.26), without In-vehicle catharsis object (M = 4.25., SD = 1.71). In traffic congestion situation, p=0.024, with In-vehicle catharsis object (M = 3.87, SD = 1.36), without In-vehicle catharsis object (M = 4.32., SD = 1.81). And we can see that the intervention effect is weaker in the congested situation than in the overtaking situation, which can be attributed to the overtaking situation, where the vehicle overtaking ahead is the cause of the driver's anger, when the In-Vehicle Catharsis Object interacts with it as the offender, satisfying catharsis theory - catharsis be beneficial when the receiver is the offender[34].

Our second hypothesis on whether In-Vehicle Catharsis Object change the angry driver perceptions about the emotional valence of frustrating driving events. The results show that In-Vehicle Catharsis Object does not differ significantly in any scenario. This can be explained by the fact that the device does not essentially solve the problem of the vehicle being blocked from moving forward, so the driver continues to feel negative.

Overall, the In-Vehicle Catharsis Object demonstrates the potential for suppressing the generation of driver anger, especially for the intervention of angry expressions - aggressive driving behaviour. This is mainly achieved by lowering the driver's angry arousal to suppress emotions towards anger and seems to have a less significant effect on emotional valence. Although the results show a very small increase in the driver's emotional valence. This can be explained by the theory of driver multisource[49], when performing a task there is competition for a shared pool of multiple resources, simultaneous tasks requiring similar resources may interfere with each other, and through In-Vehicle Catharsis Object a degree of interference can be brought about that allows the driver to be distracted from aggression inducing events and interact with the In-Vehicle Catharsis Object interaction system, thus pulling the driver away from negative emotions. Positive emotions are brought about by distracting stimuli. However, the In-Vehicle Catharsis Object interaction still leaves the driver feeling negative, it might be the In-Vehicle Catharsis Object interaction does not fully distract the driver from the current frustrating scenario and is therefore ineffective.

In addition, the interview feedback given by the participants showed that they were all very interested in this novel interaction, which they said captured their attention. The presence of the word, "Sorry" largely reduced the misinterpretation of emoji errors, more-accurately conveying apologetic feedback in response to the physical manipulation untaken by the participant and giving them a positive feeling. The mapping relation between pressure and emoji was well perceived and quickly grasped by users on the first try, suggesting that the interaction of the device was consistent with user perception. Participants reported that the presence of an In-Vehicle Catharsis Object allowed them to release their anger without honking their horns. Thus, demonstrating the potential effectiveness of the device reducing aggressive-driving tendencies. Some participants even pointed out that they would like the vehicle emojis to be more diverse, so that the interaction would be more fun, especially when waiting for traffic lights on the commute, and that this might give them additional positive feelings by interacting with the In-Car Catharsis Object.

7 CONCLUSION

The central concern of this study was how an aggressive driving-behaviour can be reduced in daily-commute driving situations. The first proposition was explored was that the competence and autonomy associated with intrinsically-motivated and extrinsically-motivated behaviour can be affected by the provision of external events and will manifest as a lack of personal control over behavioural motivation. The second proposition was that persuasive theory could be applied to enable drivers to change their aggressive driving-behaviour (from the inside out) to bring about a more-positive outcome. A user study was carried out for this purpose, using the method of video-ethnography, and it was concluded that some drivers need aggressive expressions to vent their anger. Research on cathartic displacement-behaviour and persuasive-design principles led to the design and development of the In-Car Catharsis Object. By allowing the angry driver to interact with an in-vehicle catharsis object, the anger generated by driving situations was dissipated through catharsis, thereby intervening in the generation of intrinsic- and extrinsic-motivations that result in aggressive driving-behaviour. The final test results showed that the device was effective in reducing aggressive driving behaviour, mainly through affecting the driver emotionally arousal. The effect was not so significant in terms of emotional valence, but showed some potential. Future research may be able to explore potential solutions to aggressive driving behaviour in terms of both emotional arousal and valence together, but a potential hidden danger is how to balance the safety issues for distracted drivers. This would need further investigation and testing. In addition, due to experimental conditions, the experiment only tested drivers who interacted with the vehicle emoji, but in real road conditions, where there would certainly be other people on the road, it is unclear whether the introduction of vehicle emoji into the road-traffic network would have the positive impact on others that the study envisaged.

7.1 Limitation

The user-tests conducted in this study only tested the effectiveness of the prototype for mitigating aggressive driving-behaviour when the user interacts with the In-Car Catharsis Object. It did not test when to activate the device and which set of interaction mechanisms to activate. This was due to technical and epidemiological limitations (the COVID-19 pandemic). The tests were also based on simulations and did not fully reproduce the real driving-environment, so when applied to actual driving situations, the results may vary. Despite this, with the development of artificial intelligence and its increasing use in the automotive industry, it is expected that vehicles will continue to become 'intelligent' and will, in the future, be able to recognise scenarios sufficiently well to respond correctly and activate the right mechanism at the right time, creating a closed loop of human-vehicle interaction. At the same time interactive devices are building interaction channels between the driver's own vehicle and external vehicles. This poses a challenge for v2v communication, i.e. the intelligence of the vehicle needs to be linked in tandem to form an entire road vehicle network in order to realise the aforementioned human-vehicle interaction mechanism. The current lack of a channel for information exchange and transmission from vehicle to vehicle will make the device limited in today's scenario. A further limitation was that the project experiment and interviews were undertaken in an urban of Mainland China, and the participants were all chosen from a population that accesses the internet daily and regularly uses web emoji for chatting, so they showed a friendliness to vehicle emoji. Therefore the current design may not be transferable to other environments where emoji are unfamiliar.

7.2 Future work

With urbanisation, 70% of the population is expected to live in cities in the future, which will put enormous pressure on urban transport and traffic congestion will continue to be a problem. Combined with the stresses of modern urban-life, urban roads have become a place where negative emotions are generated and expressed, with potentially deadly outcomes[22]. To begin to address this, this study has attempted to establish new ways of human-vehicle interaction that could potentially be integrated into urban road-traffic networks as emotional mediators to alleviate negative emotions on urban roads and make urban life better. Future work should explore the impact on the interaction between drivers and surrounding vehicles when the system is introduced into the road-traffic.

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