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Three Social Car Visions to Improve Driver Behaviour

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Abstract

The social cost of road injury and fatalities is still unacceptable. The driver is often the main responsible for road crashes, therefore changing the driver behaviour is one of the most important and most challenging priority in road transport. This paper presents three innovative visions that articulate the potential of using Vehicle to Vehicle (V2V) communication for supporting the exchange of social information amongst drivers. We argue that there could be tremendous benefits in socializing cars to influence human driving behaviours for the better and that this aspect is still relevant in the age of looming autonomous cars. Our visions provide theoretical grounding how V2V infrastructure and emerging human machine interfaces (HMI) could persuade drivers to (*i*) adopt better (e.g. greener) driving practices, (*ii*) reduce drivers aggressiveness towards pro-social driving behaviours, and (*iii*) reduce risk-taking behaviour in young, particularly male, adults. The visions present simple but powerful concepts that reveal 'good' aspects of the driver behaviour to other drivers and make them contagious. The use of self-efficacy, social norms, gamification theories and social cues could then increase the likelihood of a widespread adoption of such 'good' driving behaviours.

Keywords: social cars, pervasive computing, social norms, cooperative systems, Intelligent Transport Systems

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1. Introduction

Human's craving for social connectedness continues to grow. Social networks have used web technology to fulfil our insatiable need for social connectedness and has unexpectedly changed the way individuals interact with each other. Smartphone devices have brought social networks into our cars, however, due to the vehicle's safety requirements, social networks have never been fully integrated into our driving environment. Furthermore, the physical nature of vehicles such as the metal shield prevents natural social interactions between road users. Cooperative systems such as Vehicle to Vehicle (V2V) communication offer new location aware services which will allow drivers, in the same vicinity, to share and exchange situational information anywhere and anytime. This, however, raises the elementary questions proposed by this special issue, including 'who can communicate what, when, how, and why?'

The aim of this paper is to present three innovative visions that furthers the debate around those questions, in particular the question 'why'. We argue that social pressure are particularly suitable to influence human driving behaviours for the better and that this aspect is still relevant in the age of looming autonomous cars. Our visions provide theoretical grounding how V2V infrastructure and emerging human machine interfaces (HMI) could persuade drivers to (*i*) adopt 'better' (e.g. greener) driving practices, (*ii*) reduce drivers aggressiveness towards pro-social driving behaviours, and (*iii*) reduce risk-taking behaviour in young, particularly male, adults.

1.1. Why: Humans still matter

Improving transportation efficiency through operational innovation is critical as our population grows and ages, budgets tighten and consumer preferences shift. Aside from important issues such as reducing road trauma, fuel consumption and emissions, we also need future technologies to accommodate for the road users social needs. The 'Google autonomous car' is claimed to be ready for the public within 5 years whilst Volvo is predicting that within seven years "you won't be able to crash" its cars by using semi-autonomous technologies such as low-speed collision-avoidance or pedestrian detection.

Although these valuable endeavours will make significant contributions to transport and safety by removing the control from the driver; our visions complements the (semi-) autonomous technologies where the driver is still responsible for operating the vehicle at strategic, tactical and operational levels [62]. It has been shown that driver's decision making is heavily influenced by the social setting. Driving is a socially regulated behaviour [91]. Normative factors have been shown to have influence on speeding behaviour; for example, how driver perceptions of the beliefs, attitudes, and actions of their peers towards speeding can influence driving speeds [29].

The following subsections draw attention to the question as to 'how' social information will be able to be communicated in real-time. They introduce several underlying, emerging technologies that will ultimately enable our visions.

1.2. How: Intelligent Transport Systems and Cooperative Systems

Intelligent Transport Systems (ITS) concern the use of information and communication technologies applied to transport infrastructure and vehicles. ITS have the potential to reduce fatalities and injuries by 40% across the OECD [65]. Existing autonomous Advanced Driving Assistance Systems (ADAS), which are a subset of ITS, include examples such as pedestrian detection in bad vision conditions. They generally use various sensors such as radars, cameras, or lasers to gather contextual/situational information about the vehicle's surroundings (e.g., pedestrian approaching) in order to provide appropriate countermeasures (e.g., warning or breaking). However, such systems often have technical limitations. For example, the sensors' perception and awareness are limited to the immediate surrounding area of the vehicle, and this can be obscured.

Cooperative systems, which allow vehicles to communicate with each other to achieve a common goal, are widely recognised as the next big challenge in ITS (http://www.cvisproject.org). Cooperative systems can offer significant improvements in the safety of all road users by increasing drivers' awareness given that 80% of vehicle crashes are due to human errors. Cooperative systems can also improve the quality and reliability of information available to drivers about their immediate and distant environment.

Most of existing approaches consist of exchanging the current vehicle kinematics and the whereabouts of hazards between two vehicles with the view to anticipate crash avoidance. However, cooperative systems such as V2V could be used to facilitate location aware peer to peer communications between road users.

ITS resembles the infrastructure for ubiquitous computing in the car. It encompasses *a*) all kinds of sensing technologies within vehicles as well as road infrastructure, *b*) wireless communication protocols for the sensed information to be exchanged between vehicles (V2V) and between vehicles and infrastructure (V2I), and *c*) appropriate intelligent algorithms and computational technologies that process these real-time streams of information. As such, ITS can be considered a game changer. It provides the fundamental basis of new, innovative concepts and applications, similar to the Internet itself.

The information sensed or gathered within or around the vehicle has led to a variety of context-aware in-vehicular technologies within the car. A simple example is object detection, which stops the vehicle when sensors (camera or radar) detect an object within the the trajectory. We refer to this type of context awareness as vehicle/technology awareness. V2V and V2I communication, often summarised as V2X, enables the exchange and sharing of sensed information amongst cars. As a result, the vehicle/technology awareness horizon of each individual car is expanded beyond its observable surrounding, paving the way to technologically enhance such already advanced systems.

1.2.1. Limitation: Security

Cooperative systems will exacerbate the need for strong security. Driving performance, location and identity (car registration) could easily be tracked with existing technology. Privacy has been hailed as a potential major issue in cooperative systems. The human user is often the weakest link in the security chain of a software system. Changing security profile whilst driving is cognitively more challenging than performing it in a desktop environment. A poor security usability in the V2X context could lead to serious security vulnerabilities that can be exploited for criminal purpose. “The system must be easy to use and must neither require stress of mind nor the knowledge of a long series of rules” [48].

1.2.2. Limitation: Reliability of exchanged information

The Human Computer Interfaces (HCI) research community has been looking at how drivers could most effectively receive and act upon received information and how information can be delivered with the least amount of unintended consequences, such as distraction [74]. The design of HCI for cooperative applications is still in its infancy. Most in-vehicle HCI research was conducted for Advanced Driving Assistance Systems (ADAS) with the underline hypothesis that the information presented to the driver are highly accurate and reliable. Such assumptions are no longer valid in cooperative systems environments using vehicular ad-hoc networks (VANET). In previous work we have shown that the 802.11 broadcasts service, which is the building block of V2V communications, cannot be reliable [21]. Each car can have different perception of their location (e.g. by using GPS), reaching agreement between different cars about their respective relative positions requires complex data fusion and conflict resolution mechanisms which do not necessarily provide the most accurate information. In [37] we further explore the possibility of modeling and simulating the benefits of Cooperative Systems based on Inter-Vehicular Communication with the aim of implementing a freeway emergency braking scenario. While our model confirms (together with related research) that collaborative system can reduce the number of crashes, yet the average crash severity appears to remain constant, which stresses on the urgency of more work on such topics.

1.3. How: New HCI & augmented reality

Novel HCI paradigms, such as tangible, gestural and manipulative interfaces, draw their theoretical soundness from various theories of embodied cognition, e.g. Kirsh and Maglio's epistemic action [49, 56], Dourish's embodied interaction [23] and Hostetter and Alibali's visible embodiment [42]. While these works have had a tremendous impact on human-computer interaction (HCI) and particularly on Computer Supported Cooperative Work (CSCW), a translation to the road transport domain is necessary to take into account the peculiarities of the interaction between drivers. In addition, any theory or model of human machine interaction in the context of driving behaviour that fails to include social concepts could be argued to lack a critical element.

Our visions are placed in future scenarios where we assume novel interfaces to be context aware and natural to effectively convey information *when* it is safe to do so, i.e., when they do not increase the information overload of the driver.

Conceptually, our visions are irrespective of the modality of interaction, although the examples in the following sections are depicted visually. Nevertheless, given the current state of AR glasses and HUDs, we do see the biggest potential in visual interfaces to convey (so output rather than input) information in such way that it augments reality with an increased ambient, social awareness. We therefore propose to introduce these augmented reality concepts via Head Up Displays (HUDs).

In the past, HUDs have been developed and primarily used in fighter jets as a way to convey visual information to the pilots in the least distracting way. In luxury cars, HUDs are considered to be the safest way to convey visual information to the driver, e.g., speed, navigation, etc. In the not so distant future, such displays are going to enter a wider consumer market, examples include new wearable computing devices, such as Augmented Reality (AR) glasses (e.g. Google Project Glass), or HUDs specifically designed to be retrofitted in cars (e.g. Pioneer CyberNavi).

Using such technologies to convey *social* information in cars is a relatively new field. The HCI can augment the driver's social perception by adding, in his/her field of view, elements that improve social awareness, essentially creating what we refer to as the 'social car' [82] [83]. We have shown that the use of, for example, avatars on HUDs can help drivers to safely negotiate intersections [72].

1.4. Social car

As mentioned above, in this paper, we draw attention to those application areas of sensing and V2X technologies, where the driver's behavior and hence the socio-psychological perspective plays a more pivotal role. The focal points of our research around the social car is illustrated in Fig. 1. The vehicle first (1) gathers or senses social information about the driver and the driving behaviour. We purposely keep the definition of what that information might be very abstract, but will provide concrete examples in our vision sections. Generally, this information can range from broad social network information to the driver's current facial expression, or from the driver's historical driving data to the current revs of the engine.

Note, that it is not the type of information that makes it social, but the fact that it is shared. For example, applications that gather or sense information and feed it back to the driver (2 in Fig. 1) does create an increased self-awareness in itself (a simple example is the speedometer). However, as we will show in vision A, this self-awareness has the potential to be intensified through the social layers.

Hence, our definition of the *social car* is a car with the ability to share social information with other road users through V2X technologies, e.g. vehicular ad-hoc networks (VANET) [81]. Using these V2X technologies, the sensed information can then be (3) passed to surrounding drivers for an increased direct social awareness, or (4), pushed even further, into the cloud, where it is collected and visualized for an increased, collective social awareness within the driving community at large. Our visions presented in this paper focus on these levels of social awareness with a view to improve driving behaviours.

2. Vision A: Social norms and self-efficacy to motivate better driving behaviours

The development of future in-car technology interventions can borrow design strategies from outside the driving context. Previous technologies, for example, have aimed at helping users to change behaviors in order to lose weight, eat better, exercise more, stop smoking, use less energy, recycle, etc. [30]. Such experiences have contributed towards the establishment of concrete design strategies [17].

Applications specific to drivers behavior change are promising, although in their infancy, and despite evidence of their effectiveness, acceptability, perceived usefulness and possible drawbacks being still unclear (see e.g. [61, 79]. Building on the ubiquity and flexibility of smartphones, a number of application have emerged that combine personal mobile sensing and persuasive strategies, most notably with the aim of promoting a more economic driving behavior [10, 61, 96, 66, 27]

Other examples of in-car persuasive technologies include conversational entertainment systems aimed at engaging the driver [93], sensing and providing feedback on driving mistakes [7], presenting contextual information at the dashboard to prevent speeding [51] , to mention but a few.

The present vision articulates a novel approach to persuasion that leverages the role of social norms and self-efficacy in order to achieve a change in behaviour.

2.1. Social norms

Our social life is characterised by norms that manifest themselves as attitudinal and behavioural uniformities among people. Social norms can be viewed as rules and standards that are understood by members of a group, and that guide and/or constrain their social behaviour [73].

These norms emerge out of interactions with others, they may be either implicit or explicit, and sanctions for deviating from them come from within the social network itself [16]. Essentially, social norms are conventions emerging from a group of people that direct or specify how people must, should or could behave in various situations. Their influence can extend to the attitudes, beliefs and values held by group members. Social norms can be seen as a way to maintain stability among the members of a social group or community [33].

As such, social norms can have a significant influence on individual behaviour. In fact, norms are one of the principal ways that social groups influence individual behaviour and attitudes [73]. How strongly an individual is affected by the norms of a certain group is influenced by how important that group is conceived to be for the individual.

2.1.1. Using social network concepts to influence norms

It is widely acknowledged that the use of social networks on desktop or smartphone devices have shaped our shopping pattern, interaction behaviour, and education. However, social networks have not comprehensively been researched or integrated in the driving environment. One reason is that the enabling technologies are still being developed and/or are still limited (see sections 1.2.1 and 1.2.1), the other reason is that their road safety potential has not been fully recognised.

Driving context is fairly different from other contexts as it is very fluid, it has legal road rules, and requires constant cognitive attention do perform critical tasks. For example drivers cannot legally use their smartphones whilst driving. Driving is a critical task and the use of technology could potentially shift driver's attention away from the critical task and cause crashes. Driver distraction, although under reported, is estimated to contribute to 23 percent of road crashes [74].

On one hand, the use of social networks have been thoroughly investigated outside the driving context. On the other hand, a large body of research in ergonomic and human factors have been conducted in the area of Human Machine Interface (HMI) to minimise driver distraction [74]. However, the impacts of social network information on driver behaviour has not received much attention despite its potential to improve mobility, safety and carbon footprint, a shortcoming that this paper aims to address.

Changing behaviour with the use of real time Human Machine Interface (HMI) interfaces (e.g. feedback about driving performance) is a psychologically and socially complex problem. Unless the driver already holds a strong goal (e.g. to be eco-friendly), the feedback will only inform, but will not necessarily motivate sustainable action. Attitudes, beliefs and values are learned psychological constructs that have been used successfully to motivate behaviour changes (see e.g. [87]) outside the driving context. Furthermore, individuals generally respond to the actions and belief of their peers. The theory of planned behaviour (TPB) is a behavioural science theory which stipulates that a given behaviour performed by a person depends upon a combination of particular individual and social factors [4]. In the driving context, social norms have already had a regulatory role. For example, intentions to drink and drive are influenced by different factors including attitudes, probability of being caught and social norms [3].

Today, the advent of cooperative systems such V2V combined with exponential growth of social networks offers unique and unprecedented opportunities to make a targeted behaviour a contagious social norm transmitted by V2V communication.

2.2. Self-efficacy

Drivers do not simply react to their immediate environment, but are involved in complex forethought and decision making processes. A substantial body of converging evidence shows that perceived self-efficacy significantly influences human self-development, adaptation and change [9]. Self-efficacy is our belief in our ability to succeed in certain situations. Self-efficacy is a social cognitive theory in which perceived self-efficacy is a major determinant of intention. A decision based on misjudgments of our capabilities to reach a goal could produce detrimental consequences, e.g., proper appraisal of one's own efficacy has considerable value. There is no all-purpose measure of perceived self-efficacy [9]. Self-efficacy assessment has not been comprehensively used in designing feedback in driving situations. The use of self-efficacy provides valuable information on driver acceptability and driver inclination to adopt a particular behaviour in all circumstances with the view to assess the true benefits of the changed behaviour.

2.3. Example: Social sharing to create social norms and improved self-efficacy

The ability of V2V to exchange social information via new forms of in-vehicle HMI could influence different types of behaviour such as drivers' speed, eco-driving practice, aggressiveness or other aberrant driving behaviours. V2V and crowdsourcing mechanisms provide the ability to capture snapshots of general behaviour of peers (e.g. average speed on school zone). It also provides the opportunity to identify vehicles violating the social norm. Such new mechanisms will act as strong incentives for complying and belonging to the social norm.

The HMI, which conveys social information, needs to be carefully crafted to persuade users to use it. We propose to introduce augmented reality concepts to convey social cues in cars. The HMI, presented on Head Up Display (HUD), will augment the driver's social perception by adding, in his/her field of view, elements that improve social awareness. We hypothesise that an augmented reality social display will create a 'social norm', which will persuade, or positively reinforce drivers to adopt behavioural improvement in more powerful ways, based on the theoretical grounding of the effects of social norms.

For example, green leaf displays that convey how efficient a driver drives already exist in cars today. However, they are limited in a way that the information they convey is not shared amongst peers or other drivers to create a social norm (c.f. Fig. 2, where the number of green leaves shows how environmentally responsible other drivers are), nor do they convey how a driver may have improved over time in comparison to other drivers to create an improved self-efficacy. Overall, advances in V2V and HMI will allow us to design more impactful HMIs by leveraging social norms and self-efficacy theory to improve good driving behaviours, such as eco-driving, aggressiveness or speeding, from a human perspective.

3. Vision B: Sharing social cues to foster pro-social driving behaviours

3.1. The car: an isolating metal shield

Social scientist Leckie refered to cars as a 'semiprivate metal containers' [52], because driving a car is not conducive to rich social interactions between drivers. This is partly due to the car's metal shield, which tends to isolate and anonymise drivers, and prevents exchange of social cues. The metal shield prevents drivers from feeling the social presence of another human being behind another steering wheel.

Understanding the relationships that drivers form with their car and places is important to understanding interaction between road users. Cars and their immediate surrounding have been demarcated as the driver's own territory [31]. Territories exist to meet both physical and social needs, while being temporarily or permanently owned, controlled, marked or personalised, and potentially defended by occupants or owners [5]. The physical size of the territory is larger than the size of the vehicle. The overlap of territories can trigger conflicts (e.g. following too closely). The metal shield reinforces the notion of this territory and could be seen as obstructing social contacts.

Lupton [55, 54] articulates this idea in quite provocative terms: “When one is driving, one becomes a cyborg, a combination of human and machine. The notions of individual space, social norms and relationships change to suit this combination, to the point that drivers tend to humanise cars or, reversely, to relate to other drivers as machines, thus dehumanising them”.

As a result, at the steering wheel, we all experience an inhibition of our non-verbal communication capabilities with other road users. We have difficulty in establishing eye contact, in interpreting facial expressions, and in using gestures to regulate social interaction; we are limited in our capacity of pointing out our interest, intention or attention to other drivers; we feel a lack of social and emotional reciprocity. These ‘symptoms’ could well be the hallmark of autism, and yet represent a common driving situation that results in drivers often behaving aggressively towards other road users, misinterpreting others’ intentions.

3.2. The importance of social cues

It is well known that a successful social interaction relies on non-verbal cues: [6] has estimated that when two people chat, only 30% of the communication process is verbal, the other 70% is a result of indirect or nonverbal communication.

Face perception is an important visual cue, which plays a critical role in social interactions. Perceiving and understanding facial movements changes due to various type of emotions plays a central role in social communication.

Eye contact is a major social cue to driving safely. Knowing the intentions of other drivers is one of the informal road rules that drivers use to avoid crashes. Eye contact is a good predictor of attentional focus [6] and gaze direction plays a crucial role in the initiation and regulation of social encounters, including the expression of intimacy and dominance [50]. Being able to make eye contact is arguably one of the major foundations of social skills.

Gestures, in their many forms and nuances, from gesticulation to formal sign languages, are tightly related to our capacity of reasoning, remembering and making sense of the world [60, 59], spatial reasoning, such as when giving or receiving directions [42], and gesturing while explaining or memorizing complex procedures is known to lighten the cognitive load in favour of the competing task [34, 18, 44]. On the other hand, we know very little of how gesturing and non-verbal communication affects the driving task and the negotiation of shared road resources.

3.3. Social competence

The capacity of effectively and safely negotiating the shared road resource could be seen as a context specific example of social competence: i.e. the desirable skills, the status among peers, the ability to form effective relationships and achieve specific goals. Rose-Krasnos proposes a framework that defines social competence as *effectiveness in interaction* relative to specific contexts or domains, both for the self (e.g. personal goals) and the others (e.g. aspects of competence that involve collaboration and connectedness).

Among the many skills on which social competence is built, e.g. social, emotional and cognitive abilities [78], an important role is played by social skills, social communication, interpersonal communication, emotional competence, as well as the ability to respond flexibly to challenges, form effective relationships and take another's perspective, as emphasizes e.g. in [86]. All such skills seem to be compromised or obstructed when driving: for example a majority of drivers regard themselves as less risky and more skillful of the average fellow driver [92]. Despite this, drivers struggle to re-establish a channel of social communication, and *invent* means of exchanging non-verbal cues, using those tools that they have at hand: headlights, hazard lamps, blinkers, and of course, hand gestures, in what Renge has dubbed 'roadway interpersonal communication'[75].

3.4. From driver aggression to pro-social Behaviour

Adopting a pro-social behaviour is commonly considered a good driving practice [72]. Moreover, the inability to express or perceive appropriate social interactions between drivers could result in aggression, selfish driving and anti-social behaviour. In other words, driving can make us angry, and anger at the steering wheel kills.

In a recent survey 50% of drivers admitted to have verbally abused another driver; remarkably 82% of them felt such act to be justified [2]. Driver aggression can take many forms. Soole and colleagues report that a larger majority of cases consist of mild aggression (such as verbal abuse, obscene gestures and tailgating). However, up to 18% of motorists reported severe aggressions, e.g. having been chased, run off the road, or assaulted [88]. It is difficult to estimate how aggressive driving contributes to crashes, partly due to a lack of consistency in the use of terms such as driver aggression, hostile or angry driving, road rage, etc. [24]. Although the cases of road anger escalating to physical aggression are relatively unusual, several studies show that aggressive driving is associated with increased risk of crashes [88], and aggressive behaviour has been reported to be a contributing factor in a majority of crashes [1].

The reasons why drivers are so prone to getting angry are not limited to isolation and anonimity. Personal and situational factors, such as age and sex, previous anger or stress, competitiveness, sensation seeking, anonymity, road congestion and time pressure, all participate to exacerbate anger episodes [64].

Subjective interpretations of the behaviour and motivation of others represent however one major factor. Anger, when articulated, is an important component of social interaction; it has the function of soliciting cooperation or apology from a supposedly offending person, or to direct accordingly the blame of onlookers. In face to face interaction, anger typically cools down as soon as an acknowledgement is received [68]. In the car, attempts of expressing anger and receiving feedback or apology are limited: social cues such as voice tone or face expressions are unavailable unless overly exaggerated, and cannot promptly reach other drivers. Similarly, the offending driver will only receive over-amplified expressions of anger. Such disproportion and the lack or delay of feedback exacerbates issues of anger [67].

3.5. Sensing and sharing social cues to reduce driver aggression

In our vision, future cars will exploit V2V infrastructure to support and enhance drivers' social competence. Existing sensors can detect, interpret and transmit different forms of emotion [11]. In-vehicle technology combined with cooperative systems can be used to convey social cues (in this vision, these cues include eye gaze direction, facial or emotion expression) which can be collected with in-vehicle sensors.

Sensing technologies for driver behavior and *natural user interfaces* are reaching their maturity and are in some cases ready for adoption in industry, e.g. drowsiness detection and voice activated commands. Other technologies, though promising as research topics, are still young and immature, but developing fast. Techniques and tools exist that are capable of classifying the emotional state of a subject from (combinations of) streams of signals [19, 13, 12].

Such signals include linguistic and paralinguistic cues in speech [45, 46, 85] and have been proven to be effective despite of the challenges related to the typically noisy environment in the car [84, 36].

Physiological measures (e.g. heart rate, blood pressure, galvanic skin response, respiration rate), though generally more invasive, deliver substantially more accurate measures of emotional arousal. MIT's SmartCar project compared electromyogram, electrocardiogram, galvanic skin response and respiration, and trained appropriate recognizers to an impressively accurate prediction rate[39].

Using facial expressions indicator of emotional arousal is obviously less accurate, but it has the distinct advantage of being more accessible [83]. Furthermore, it can be combined with other modalities, such as speech, for better recognizing the emotional state of the driver [41].

Attempts have also been made to recognize context information (e.g. traffic conditions, presence of pedestrians) and corresponding behavioural patterns on the drivers' part (such as eye gaze and body posture) with the goal of predicting their attentiveness and intentions [95, 94].

Gestures have been explored as a means of controlling the in-vehicle information system (e.g. [8, 25, 77, 26, 35, 22]). The rationale behind such explorations is that gesture based interaction could reduce the visual demand of secondary controls. Note, however, that scientific evidence of an advantage for gesture based interfaces over more traditional paradigms, with respect to driver distraction, is still missing [69].

Finally (though without any aim of being comprehensive), eye gaze in the car has been extensively used in road safety and ITS studies [72]. For example, previous research has demonstrated that perceiving the eye gaze of other drivers could influence driver behaviour [71], promoting a pro-social behavior.

Despite the many challenges and open research topics, natural interfaces, such as those ones based on gestures and manipulations, could have the potential to foster and reward a pro social behavior. Positive evidence comes from a domain as far as health care. Tangible User Interfaces [97, 43] have been found to induce more cooperative and social behaviors in children with Autism [80] [28], encouraging turn taking and shared attention. Socially assistive robots have been proposed to foster and facilitate the interaction between patients and therapists and as a replacement for living pets in pet therapy [14, 58, 57]. Shape and format of socially assistive robots varies greatly, from socially proactive robot pets, to 'intelligent toys' that reward the patients when they positively interact with the therapist. El Kaliouby and colleagues provide a discussion of how affective computing can draw insights from the experiences and literature related to social spectrum disorders such as Autism [47]. Our aim is to achieve analogous results in the car, as described below.

3.6. Example: technology mediated social cues to restore non-verbal communication

Fig. 3 illustrates our vision. When approaching a busy urban intersection, the driver is assisted in the decision making and in the appraisal of the overall driving situation by devices and displays that enrich the social car.

Ad-hoc sensors, worn by road users or fitted in the vehicle, will recognize a broad range of context information and socially relevant cues. In this figure, the pedestrian (A) is attempting to establish eye-contact and is waving a hand gesture towards the driver. The yellow car (B) is about to turn right, which can be inferred by patterns of eye-gaze and head pose of the driver. The red car (D) is conducted by a learner. The cyclist (E) is signalling her intention to turn left. At the same time, sensors in the car (C, F, H) are constantly monitoring the behavior and actions of the driver, which will be transmitted to the other road users and made available via appropriate interfaces, which can have diverse forms and shapes, ranging from a) haptic vibrotactile feedback (G) at the steering wheel to b) visual alerts overlayed to the windscreen (augmented reality), to c) wearable or implanted devices.

The implementation of a scenario such as the one described here involves the orchestration of cutting edge sensor technology and advanced visual interfaces. As we have thoroughly discussed in the previous sections, the building blocks of this scenario are available, but have rather been used towards the creation of advanced driver assistance systems, than in the view of supporting socially oriented in-vehicle information systems.

On the opposite, in pursuing our vision, we rather explore the applications of such enabling technologies to the collection and sharing of socially relevant cues. Once the sensors installed in the car have detected the potential conflicts occurring in the scene, the visual representation depicted in the figure is created and projected in order to reduce the ambiguity and hence the risks. Thus, the implementation of the overall vision is the common aim of several smaller initiatives that we are conducting within our lab, each one focused at exploring a specific research issue, and each one described in depth in the the works briefly summarized below.

In [83] we focus on emotion detection as a case study for the recognition and communication of social cues to enrich the way we communicate and address conflicts when driving. We argue that although most (if not all) efforts in the machine learning domain are aimed at achieving higher recognition rates for those emotions that are more widely and consistently recognized across cultures, such as anger, disgust, happiness, surprise, fear and sadness. We have argued that in the driving context these emotions make little sense, and efforts should instead be focused at distinguishing expressions (or moods) that are desirable or not when driving.

In [89] we further explore the use of surrogate measures such as facial expression (emotion) and head pose and movements (intention) to infer task difficulty in a driving situation, showing that a fairly high accuracy can be obtained even on low cost hardware, such as a personal mobile phone.

Such results help to overcome some of the issues related to the cost of deployment; it is evident, however, that the development and tuning of sensing technology is challenging, and a lot of work is yet to be done in order to have affordable and reliable sensors capable of recognizing complex human behavior.

Even more challenging, however, is the presentation to the driver of such a massive amount of socially related information. The very decision of what information is relevant appears not trivial, as we explore in [81, 82] and discuss further on.

In [71, 72] we explored the possibility of reducing driver aggression by humanising cars in traffic situations by representing other drivers through overlayed human-like avatars. In [90], we further explore several possible HUD interfaces in a driving simulator study that aimed at visualizing social cues. We especially focused on applications aimed at mitigating driver aggression, each interface was designed to address one or more main contributing factor of aggressive behavior: anonymity, social isolation, emotional isolation, competitiveness, territoriality, stress.

The initial results from our experiments provided precious insights into the technical feasibility of the scenario described here, but also a view of the complexity of the problem. While a detailed report on such works has been presented elsewhere [90, 89, 83], it is important to note here that the successful implementation of our vision for the social car passes through the understanding of the complex social interactions that occur among road users before being able to sense, recognize, and ultimately mediate, such interactions.

4. Vision C: Social cars to reduce risky driving

4.1. Significant over-representation of young males in road crashes

Worldwide, over a million people are killed and an additional 50 million are seriously injured on roads annually [76]. The heaviest toll is paid by young drivers [70]. Young male drivers are at a substantially higher risk of committing and repeating speeding offences [99] and being involved in speed-related fatal accidents [53]. Young male drivers are also more likely to be distracted while driving, especially through mobile phone use [15] an issue authorities struggle to address.

4.2. Boredom prone young male drivers are driven to distraction and risk

There are many underlying factors for the over-representation of young males in motor vehicle crashes. One of those factors is that young males often score highly on sensation seeking measures, and therefore tend to be prone to boredom ([100][98][40]).

Boredom directly correlates to sensation seeking, but has only received limited attention to date [38]. Boredom is defined as a 'state of relatively low arousal and dissatisfaction, which is attributed towards an inadequately stimulating environment' (p.3 [63]). In the driving context, boredom leads to the following problem: If the driving environment is not providing enough stimulation, young male drivers tend to *seek sensations* by taking risks (see Fig. 4); this includes increasing their speed or diverting their attention away from the driving task [32], e.g. by texting.

The challenge in addressing this core problem is the fact that proneness to boredom (and sensation seeking behaviour) is a hardwired personality factor in young males [38]. This means that it cannot be changed and that existing road safety strategies such as education programs, punitive fines or awareness campaigns are conceptually flawed in addressing it. Indeed, the paucity of research on strategies that tackle driver boredom left authorities unable to deal with technologies and devices that enter the safety critical car space.

4.3. From foe to friend: Using social computing devices to aid in safer driving behaviour

Authorities and the road safety community often perceive new social technologies that enter our cars first and foremost as a threat that aggravates risky driving behaviours by distracting drivers. Alarmingly, many road safety researchers tend to focus on their safety impacts only after they have started to be used inside cars, cf. smartphones and texting [15]. Regardless of punitive strategies, new technologies will continue to be used within the car, especially by young males who are early adopters. New distracting ubiquitous computing devices fulfilling our insatiable need for social connectedness will enter the car space in the foreseeable future, which could pose an even greater challenge to road safety, e.g., new wearable computing devices, Augmented Reality (AR) glasses (e.g. Google Project Glass) and Head Up Displays (e.g. Pioneer CyberNavi). To address this imminent road safety problem, a conceptual breakthrough is needed. Instead of indiscriminately and futilely rejecting and demonising such technologies, this vision aims to encourage the discovery of new ways to capitalise their usage towards bringing about safer driving practices.

4.4. Curing boredom by safely providing stimuli when needed

Above, it was established that: 1. Young male drivers are prone to boredom; 2. Their need for stimulation is hardwired and not modifiable; 3. Boredom leads to risky driving behaviour; and 4. Existing strategies are conceptually flawed and ineffective. Consequently, there is an urgent need to find innovative ways to provide alternative stimuli while driving when needed and when it is safe to do so with the view to curb the road toll. At the core of this visionary research lie the following questions: How can innovative technologies be designed to make safer driving behaviours equally or more pleasurable and stimulating than risky driving behaviours? Can the alternative stimuli be grounded in our need for social connectedness? Can they be designed in a way that they replace seeking risky driving stimuli, hence reducing risky driving (Fig. 5)?

This concept is innovative in that it represents a paradigm shift. It is neither oblivious to road safety risks nor is it using a patronising approach by telling young male drivers what not to do without offering them an alternative to satisfy their need. It follows the hypothesis, that providing safe, driving-related and emphpleasurable stimuli through digital, social technologies in the car can replace the urge for risky driving behaviours in young male drivers. The theoretical grounding is based on the premise that these additional stimulations can break the boredom, hence diverting the attention back towards the safe driving task and away from seeking stimulations through risk taking. Overall, this as yet unexplored concept articulates the notion of pleasure and safety in one technology intervention with the view to reduce injuries and fatalities. This notion was developed through a pilot study [82] and evaluated in the road safety domain [81].

Conceptually, this approach is similar to the Australian Government's "Swap It! Don't stop it!" campaign (www.swapit.gov.au), which encourages Australians to swap bad habits with healthier alternatives, or the Volkswagen Fun Theory initiative (www.thefuntheory.com), which presents ideas that make good behaviour more pleasurable or appealing than bad behaviour. For example, the Speed Camera Lottery rewards drivers complying with the speed limit with the chance to win a lottery financed by fines paid by speed offenders. By making good behaviour fun, it reduced average speeds from 32 km/h to 25 km/h.

The hypothesis presented above leads to the following research questions: What are driving-related and pleasurable stimuli for different driver archetypes, particularly boredom prone young males? How can new technologies be designed to safely provide pleasurable stimuli at the right time? Do pleasurable stimuli have safety benefits by replacing the urge for risky driving behaviours?

4.5. The 'what' brings pleasure and safety together

The concepts of pleasure and safety have conventionally been portrayed to pull apart from each other (Fig. 6). Car manufacturers and the research community around Automotive User Interfaces aim to unite the pleasure of driving and road safety by focusing on the question as to *how* a driver can safely interact (output/input) with various types of data or information without causing driver distraction (Fig. 6). The question *how* to safely output or input information undoubtedly pushes the technological advancements, making in-car Human-Machine (HMI) and Human-Computer interaction (HCI) safer. However, the *'How'* is only part of the solution. The actual information or applications (the *'What'* in Fig. 6) that form the basis of in-car HMI/HCI research have not changed much in recent years. They generally include tasks such as writing/reading SMS, emails, or more recently tweets and social media status updates; dialling or making phone calls, selecting from lists of the in-car entertainment system; operating the navigation system; or, exploring points of interest. Little attention has been paid to new types of content and applications.

4.6. Example: Rewarding achievements

Online platforms often use socially grounded gamification or ratings to increase fun and engagement, motivate users to come back to use the system, or enforce certain behaviours or etiquettes. E.g., in Foursquare, users can claim mayorships, unlock badges, receive special offers & rewards from retailers while also tracking against friends via a leader board [20]; on eBay, buyers and sellers rate each other to encourage fair trading.

This vision seeks to translate these concepts (without being limited to gamification and rating systems) to road safety in order to stimulate drivers with engaging, driving related tasks when they are being understimulated and to, e.g., motivate drivers to drive more safely and courteously.

A simple example to illustrate this concept is depicted in Fig. 7. It shows an augmented reality application that allows drivers to a) rate each other, b) accomplish save driving related achievements by being rated and c) view each other's achievements. Adding such a layer of playful engagement obviously requires save interfaces for inputting and outputting such information, but conceptually it could stimulate the driver with a playful, driving-related task that keeps them 'distracted' (in a good way) from other risky driving decisions, such as speeding.

As mentioned, this presents just one example to illustrate the concept. However, we will explore this innovative approach to road safety in more detail in the future. As demonstrated, the literature in social and psychology research provides the basis to pursue this vision in greater detail.

5. Conclusion

The social cost of road injury and fatalities is still unacceptable. The driver is often the main responsible for road crashes, therefore changing the driver behaviour is one of the most important and most challenging priority in road transport.

Human's craving for social connectedness is alleviated with the increasing use social networks. However we have shown that social connectedness is somehow restricted in a car. Social theories stipulate that one of the most sustainable ways to change individual behaviour is to influence peers. Social norms are used to provide a "scheme" on the appropriateness of our own behaviour. There is a plethora of theoretical evidences demonstrating that social concepts could influence driver behaviour. Social networks, used and adapted in the driving context, can harbor a flow of desirable moral values such as safety or green driving behaviour.

Tackling crucial road transport problems such as agressivity, eco-driving and safety with social information, conveyed with V2X is an innovative approach. We introduced a simple but powerful concept. It consists of revealing "good" aspects of the driver behaviour to other drivers and make it contagious. The use of self-efficacy , social norms and gamification theories could increase the likelihood of a widespread adoption of such "good" behaviour.

The use of such social information could make driving more humane. Hence, we have shown how V2V could convey and establish social norms with the view to positively influence driver's behaviour. Specifically we showed how V2V could (*i*) break the vehicle's 'social' shield, (*ii*) provide a better perception of 'presence' of other road users, (*iii*) shift our perception of acceptable driving practices (*iv*) reduce agressivity and (*v*) improve road safety.

Cars and V2V have never been on the spotlight for being able to change behaviour and spread such moral values. The idea that one's behavior and actions can influence not only the drivers in the vicinity but also the others connected in our social network is a very powerful concept worth investigating for future research. Testing and validating such idea needs to be conducted in naturalistic settings as real-time in-vehicle information is likely to impact positively or negatively on driver behaviour. The net benefit of our proposed concepts is subjected to driver acceptance and market penetration.

In the future, our behavior, actions, beliefs and habits are likely to be largely more influenced and impacted by social networks and social media supported by cooperative systems than we ever could have imagined.

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List of Figures

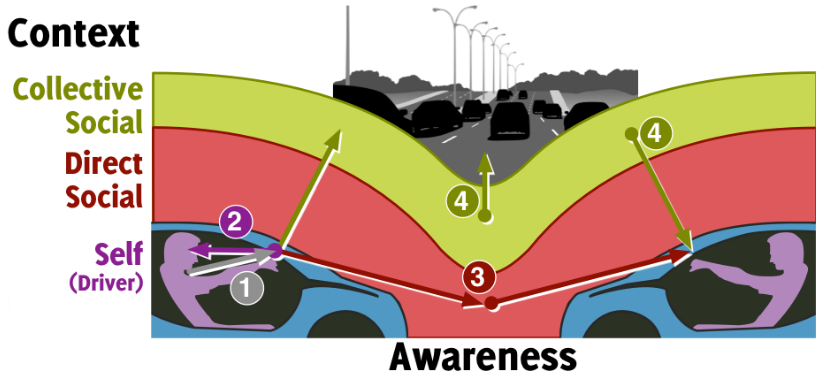

Figure 1: The social awareness layers around the social car

Figure 2: The green leaf display showing consumption of other drivers

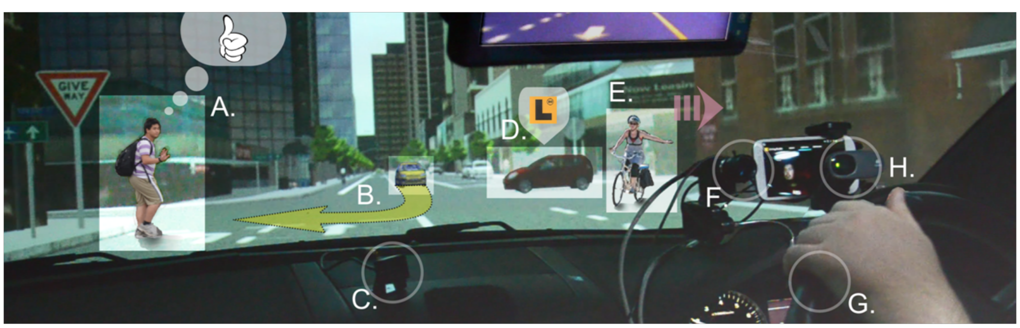

Figure 3: Sharing social cues to reduce driver aggression

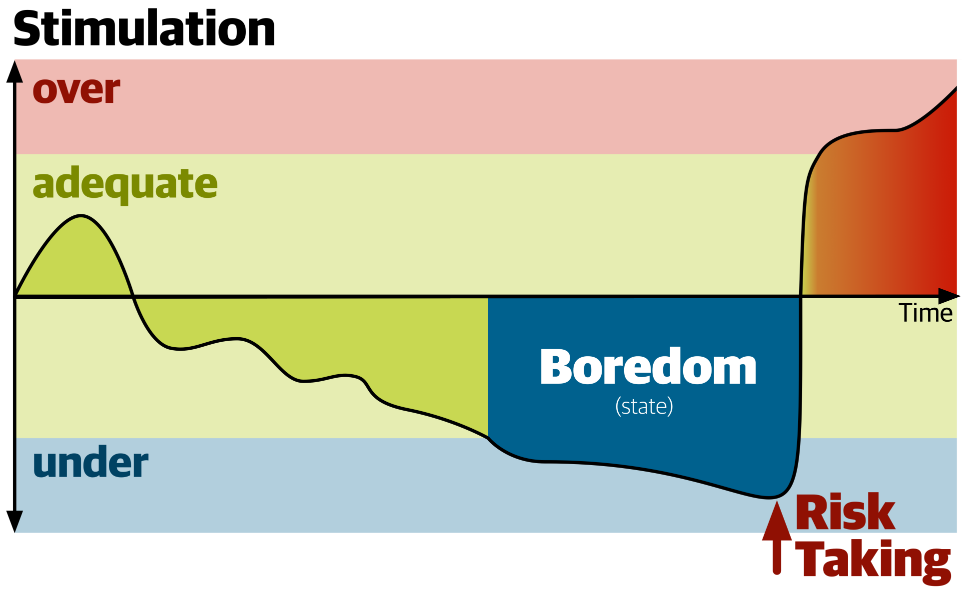

Figure 4: Under and Over stimulation - boredom and risk

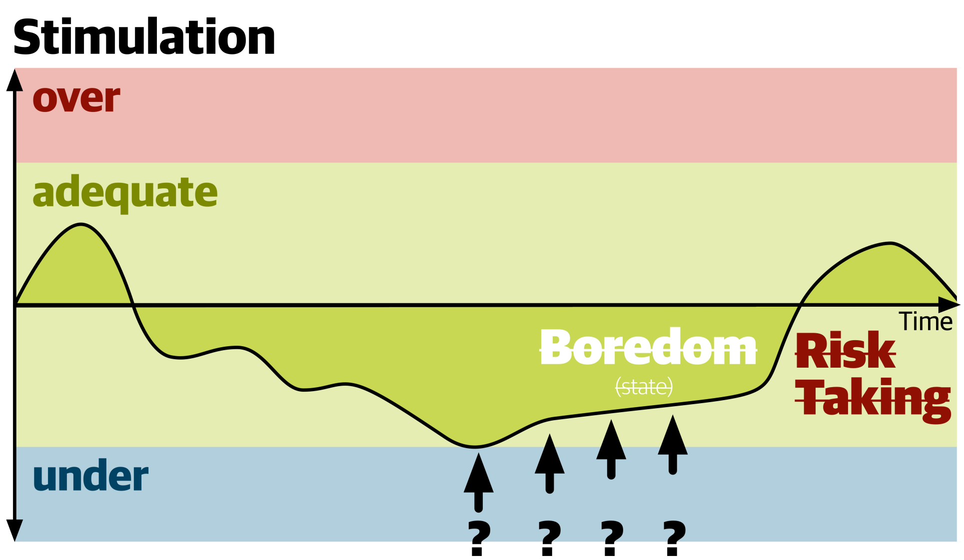

Figure 5: Under and Over stimulation - Intervention

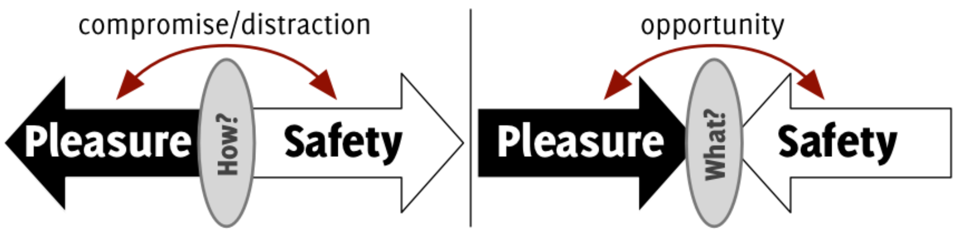

Figure 6: The what that brings pleasure and safety together

Figure 7: Rating other drivers and receiving badges for good driver behaviour