The future shape of digital cars

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Abstract

Background Digital information is increasingly becoming available on all aspects of the urban landscape, anywhere and anytime. Physical objects (c.f. the Internet of Things) and people (c.f. the Social Web) are increasingly infused with actuators, sensors and tagged with a wealth of digital information. Urban Informatics explores these emerging digital layers of the city. However, very little is known about the challenges and new opportunities that these developments may offer to road users. As we gradually spend more time using our mobile devices as well as our car, the tension between appeasing our craving for connectedness and road safety requirements grow farther apart.

Objective The aims of this paper are to identify (a) new opportunities that Urban Informatics research can offer to our future cars and (b) potential benefits to road safety.

Methods 14 Urban Informatics research experts were grouped into seven teams of two to participate in a guided ideation (idea creation) workshop in a driving simulator. They were immersed into different driving scenarios to brainstorm innovative Urban Informatics applications in different driving contexts. This qualitative study was then evaluated in the context of road safety.

Outcomes There is a lack of articulation between Urban Informatics and Road Safety research. Several Urban Informatics applications (e.g., to enhance social interaction between people in urban environments) may provide benefits, rather than threats, towards road safety, provided they are implemented ergonomically and safely.

Conclusions This research initiates a much-needed dialogue between Urban Informatics and Road Safety disciplines, in the context of Intelligent Transport Systems, before the fast approaching digital wave invades our cars. The dialogue will help to avoid driver distraction issues similar to mobile phones use in cars. As such, it provides valuable information for future regulators and policy makers in charge of shaping our future road transport landscape.

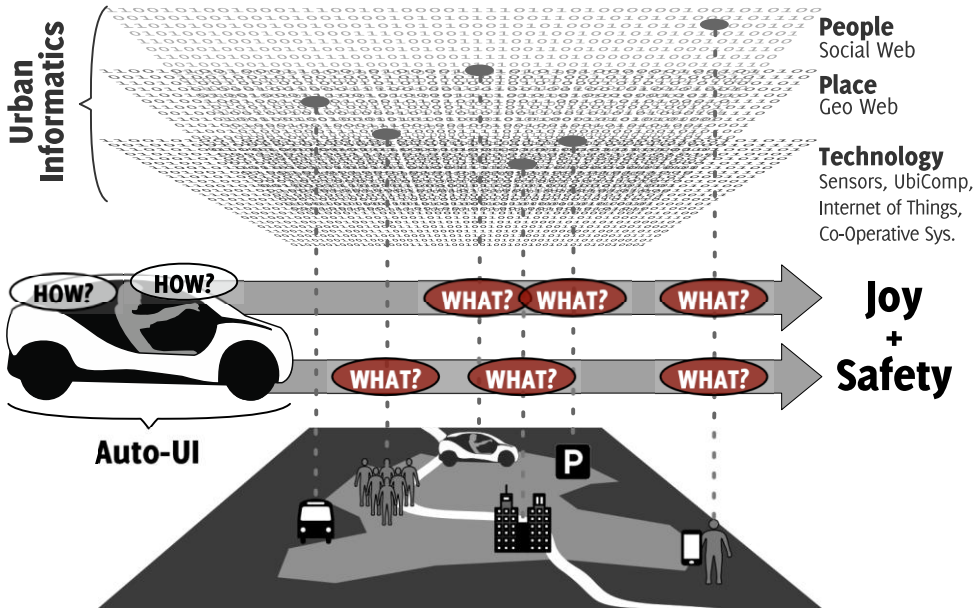
Key words: Intelligent Transport System, Urban Informatics, Social Media, In Vehicle Information Systems.

1. Introduction

Place- and time-specific digital information is increasingly becoming available on all aspects of the urban landscape. People (cf. the Social Web), places (cf. the Geo Web), and physical objects (cf. ubiquitous computing, the Internet of Things, or Co-Operative Systems in the automobile context) are increasingly infused with actuators, sensors, and tagged with a wealth of digital information. *Urban Informatics* (Foth, 2009) explores these emerging digital layers of the city at the intersection of people, place and technology (Figure 1). With the majority of the world's population now living in urban environments, and Australia leading this trend at over 89% (United Nations, 2008), these digital layers are playing an increasingly vital role for an urbanised human race living in today's mega cities in terms of various dimensions of sustainability: social, environmental and economic.

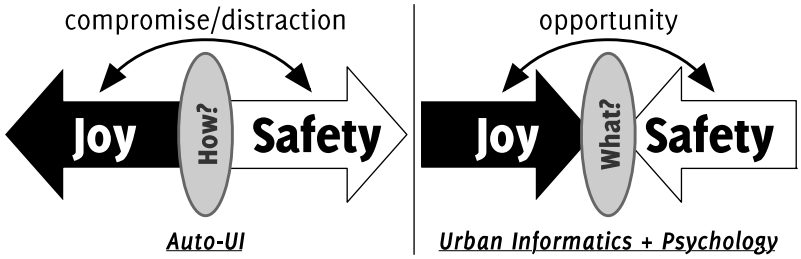
However, little is known about the challenges and new opportunities that these pervasive digital layers may offer to road users as they are moving through the city. Car manufacturers and the research community around Automotive User Interfaces and Interactive Vehicular Applications (Auto-UI) aim at bridging the compromise between the joy of driving and road safety (Figure 1 and Figure 2). As we gradually spend more time using our mobile devices as well as our car, the distance between appeasing our craving for connectedness and road safety requirements grow farther apart.

Figure 1: A driver passing through different digital layers of the city (based on Calabrese, Kloekl & Ratti (2009))



It is a challenging task to advance the state of the art in vehicular user experiences, in order to make cars both safer and more enjoyable places to spend time, because the concepts of joy and safety seem to contradict each other (left, Figure 2). For example, some young drivers are thrilled by speed and the roar of the engine. The enjoyment of risk taking behaviour such as racing or loud music has been shown to increase crash risks, particularly in adolescent peer groups. Safe driving behaviours are often seen as a boring activity, restricting the freedom of a driver and take away the fun. Furthermore, the tasks that may bring joy to a driver could have unwanted effects and compromise safety by distracting the driver. The use of social media is a task that brings joy to the user, but driving is a critical and complex task, which cannot easily accommodate the use of social media.

Figure 2: Bringing joy and safety together



At the heart of overcoming this conundrum lies the question as to *how* a driver can *safely* interface (output/input) with various types of data or information (cf. Figure 1 and Figure 2), without causing driver distraction. The question *how* to safely output or input information pushes the technological advancements of in-car human-machine (HMI) and human-computer interfaces (HCI). As a result, head-up displays, which are widely considered a safer way *how* visual information is displayed to the driver (Weinberg, Medenica, & Harsham,

2011), are becoming increasingly available, e.g., Pioneers augmented reality Cyber Navi product, an aftermarket head-up display system that can be retrofitted into any existing car, will go on sale in the Japanese market in July 2012[1]. Other information may be safer to convey to the driver via audio (e.g., warning sounds) or haptic feedback (e.g., vibrating steering wheel or seats and seat-belts (A. Riener, Ferscha, Frech, Hackl, & Kaltenberger, 2010)). Recommender (Bader, Siegmund, & Woerndl, 2011), summarizing, or context-aware systems (Tchankue, Wesson, & Vogts, 2011) aim to understand *how* the driver can be provided with the appropriate amount of information at the right (safe) time. Lastly, improvements in input technologies such as speech (J Cuřín et al., 2011) or gesture recognition (Andreas Riener & Wintersberger, 2011) or more driver-friendly controllers (Kujala, 2009) offer safer techniques *how* to create, select or interacted with the presented information.

The actual information or applications that form the basis of human-machine interface (HMI) research for in-vehicular information systems (IVIS) have not changed much in recent years. They generally include: writing/reading communication texts such as SMS, emails, or more recently tweets and social media status updates (J Cuřín et al., 2011); dialling or making phone calls; selecting from lists of the in-car entertainment system (Weinberg et al., 2011); operating the navigation system; and more recently, exploring points of interest (Kujala, 2009).

Little attention has been given to new types of content and applications. In fact, in our review of past research papers presented at Auto-UI conferences, we only identified one paper that investigated "which types of content are considered to be useful for in-car entertainment by drivers" (Alt et al., 2010), but this exploration was limited by the selected survey methodology, which offered pre-selected answers such as news, weather, cartoons, etc.

The road safety research community, on the other hand, have mainly focused on safety impacts of new technologies after they have invaded our cars: the mobile phone, or navigation systems for example, which cause safety concerns with regards to driver distraction. To our knowledge, the road safety community have not investigated how future technology trends such as social media could affect driving behaviour. Urban Informatics and Auto-UI have made significant advances in the use of future technologies. However there is a lack of dialogue between the disciplines of Urban Informatics, Auto-UI and Road Safety to collaborate towards the safe integration of these emerging technologies and opportunities.

2. Research approach

This project attempts to fill such a gap by posing the following research questions from two different perspectives:

RQ1 – The Urban Informatics perspective: *What* urban informatics data/information or applications can offer new opportunities to our future cars, in particular with regards to balancing joy and safety? (Cf. *4. Results*)

RQ2 – The safety perspective: What potential, new benefits do urban informatics data/information or applications offer to road safety? (Cf. *5. Discussion*)

We argue that the advancements in mobile and Auto-UI technologies over the past years turn the above into timely questions. Revisiting the question about the "*what"* in RQ1 may unlock new opportunities of bringing the concepts of joy and safety together (cf. Figure 2). This paper presents the initial step towards answering this question, focusing on available data and possible futuristic applications. Their potentials towards enabling joy and safety need to be further explored in the future. Overall, the paper also aims to encourage a fruitful dialogue between the disciplines of urban informatics, road safety, and Auto-UI towards a common research goal.

[1] http://pioneer.jp/press/2012/0508-1.html

3. Methodology

N=14 urban informatics research experts (4 academic staff and 10 PhD students) with drivers licenses between 25-45 years of age and early adopters of mobile technologies and location-based services were recruited through the university's research lab in that area. They were grouped into seven pairs of two to participate in a guided, 1-hour ideation (idea creation) workshop inside an advanced driving simulator. One of the two participants was seated in the driver's seat; the other participant was seated in the front passenger seat, with one of the authors as facilitator seated on the backseat, as well as a research assistant operating the simulator.

Real-world driving videos were displayed on the projection screen in front of the windscreen to simulate common driving scenarios. The videos were specifically recorded for this purpose and featured inner city, inner-city bypass and highway routes familiar to the participants, as well as a typical suburban and scenic route of the surrounding area. Participants were not asked to drive the simulator, they were only asked to watch the videos through the front windscreen, and immerse and imagine themselves in different driving scenarios (e.g., going shopping, driving home from work, a weekend trip with the family). The goal was to allow participants to focus on a brainstorm activity about urban informatics type of applications specific to the driving context.

The questions and tasks that guided the ideation workshop were the following: If there would be no constraints about what is technically possible and safe, what kind of information (data, text, images, video, sound, etc.) would you personally like to be conveyed to you in these different driving contexts? And from your professional perspective, what kind of urban informatics types of data could you envisage to be conveyed to future drivers?

The ideas were recorded, summarised and categorised. The summary of the results were then presented back to 10 of the previous participants in a 2-hour focus group two weeks after the initial ideation workshop for further in-depth discussions. The focus group was facilitated by the same researcher as the ideation workshop and assisted through note taking by another researcher and author of this paper.

4. Results

A rich list of ideas emerged from the ideation workshop with the Urban Informatics researchers. Reflecting upon the methodology, the immersive environment appeared extremely helpful for participants, as did the selection of familiar routes. This is cemented by the fact that the focus group discussion that followed did not reveal any additional ideas, but it did provide further insight.

The purposefully broad research question of this study led to a wide range of in-car application ideas, including:

- **safety** related applications already being explored within co-operative systems or advanced driving assistant systems (ADAS) research (cf. *technology* layer in Figure 1).
- **points of interest (POI)** applications that retrieve geo-coded information from the internet, allowing drivers to a) find locations or businesses of particular interest more easily, e.g., toilets, vegan restaurants, the cheapest petrol station, or b) retrieve additional information about local landmarks, shops, restaurants, events, etc., similar to the mobile phone applications Wikitude[2], Urbanspoon[3] or Yelp[4] (cf. *place* layer in Figure 1).
- **social location-based** applications similar to Google Latitude[5], allowing drivers to find friends or family more easily, e.g., when picking them up from unfamiliar locations.

[2] http://www.wikitude.com
[3] http://www.urbanspoon.com
[4] http://www.yelp.com
[5] https://www.google.com/latitude

- **entertainment and games**, which included creative ideas such as *SingStar on Wheels*, a singing competition application played with surrounding drivers, or a music application that automatically selects music tailored to specific driving scenarios or contexts, e.g., a song that suits a specific scenic drive or calming music when the driver seems stressed or aroused.
- **civic applications** allowing drivers to a) easily report road maintenance requests similar to mobile phone applications like FixVegas (Foth, Schroeter, & Anastasiu, 2011) or b) allowing drivers to gather/bookmark information and optionally provide feedback about local construction sites or proposed developments that affect driving in a particular area.

In addition to the ideas above, the following caused the most discussion amongst participants:

4.1 Life organisation, management and automation

Location-based reminder applications have been around on GPS enabled smartphone platforms for many years (Sohn et al., 2005) . They allow users to get reminders on their mobile based on their physical (geographic) location, e.g., remember to pick up flowers when leaving work.

More recently, apps like Locale[6], Tasker[7] or on{x}[8] allow users to define more sophisticated "recipes" that automate one's life by automatically carrying out specific tasks or actions based on specific contexts (e.g., time, date, location, event, gesture). These applications will allow scenarios such as automatically ordering a coffee when approaching the cafe at one's workplace in the morning, or automatically sending apologies to meeting participants when running late for a meeting. While these ideas are not particularly innovative anymore, they are becoming increasingly user-friendly and widespread.

4.2 Connecting with nearby drivers

Social scientists have long lamented about the effect of cars on today's urban social fabric: "Cars have removed people from the public side-walk and the possibility of chance encounters with friends and strangers alike. Encased in *semiprivate metal containers*, few of us have the opportunity to physically interact with others in our day-to-day travels" (Leckie & Hopkins, 2002, p. 329).

In recent years, the Internet has developed into an increasingly social as well as place-specific medium (Gordon & de Souza e Silva, 2011). Similarly, the following examples will illustrate a trend that may parallel automotive user interfaces and interactive vehicular applications design. The car of the future will not only be safe, but also socially embedded and geo-aware.

The urban informatics researchers saw untapped potential in the communicative opportunity presented by the drivers and passengers in nearby cars. The brainstormed applications that the participants felt were the most innovative, were about sharing spoken words, text, pictures, music, videos, tips, knowledge, reminders, games, experiences, destinations, etc., with people surrounding the car. A selection of examples that we identified as opportunities particularly for bringing the concepts of joy and safety together is now discussed in more detail in turn.

4.2.1 Driver(s) to driver(s) communication

During the study in the simulator, it became very apparent that the Urban Informatics researchers, who are all early adopters of mobile technologies as well as licensed drivers, felt very restricted in the way they could communicate and connect to other drivers. The way

[6] http://www.twofortyfouram.com/
[7] http://tasker.dinglisch.net/
[8] https://www.onx.ms

we communicate today is often limited to honking the horn, flashing the lights or various hand gestures. For them, the notion of the car being a “semiprivate metal container” (Leckie & Hopkins, 2002, p. 329) does not need to hold true in the future. Today, mobile apps such as Yobongo[9], HeyTell[10] and Twitter[11] already allow hyperlocal texting with nearby strangers. All participants wanted to see similar ad hoc chat functionalities within the car that enables them to a) communicate with one specific driver (note: not only negatively to tell others that they are an idiot, but also positively to thank them, to apologise after a mistake, or remind them that their tyres are flat) or b) with a community of drivers, e.g., to discuss or inform others of the reasons for being stuck in traffic.

4.2.2 Rewarding achievements

Typical urban informatics type of applications for mobile phones include Facebook’s location services or foursquare[12]. These applications are usually used on the go. They allow users to virtually check-in to real-world places and leave tips for others. In addition, gamification techniques are used to motivate users to come back and continue to use the system in a joyful way. User can claim mayorships, unlock badges, or receive special offers and rewards from retailers while also tracking against friends via a leader board.

Figure 3: Rating other drivers and the crowd-sourced achievements (badges[13])

Gamification is not only used to increase engagement and fun, but also to motivate desired user behaviours in online platforms. Online Q&A forums such as Stack Overflow[14] successfully reward users with points or different badges when positively contributing to the ideal of the site, e.g., helping other users.

Exploring well-executed gamification techniques could lead to innovative applications that motivate drivers to drive more friendly and hence safely, while having fun doing it: e.g., drivers could be allowed to rate the behaviour of other drivers. These crowd-sourced ratings could then be used to reward drivers with badges for friendly or consistent driving, courteous way-giving, good parking, minimal breaking, etc., which in turn could be displayed to other drivers (Figure 3).

4.2.3 Allowing social expression

Many social web users of today willingly and joyfully share personal information such as current mood, trip destinations, etc., on web 2.0 platforms such as Facebook, Google+ or Twitter (the latter providing more anonymity). It makes them feel more connected (Köbler et al., 2010). This information can be useful to drivers in many different ways.

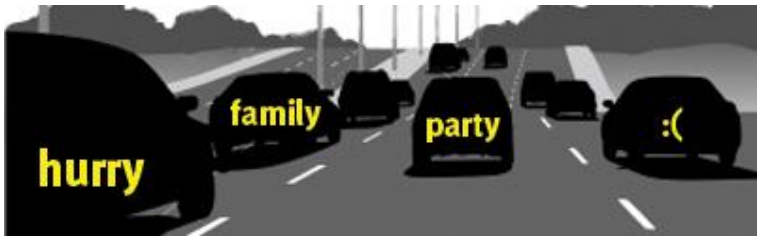
The SENSEable City Lab at MIT, for example, analyses the aggregate data originating from geo-tagged tweets to evaluate the overall driver sentiment on a particular road, which, combined with weather, incident and traffic data, forms part of a Road Frustration Index[15].

[9] http://www.yobongo.com/
[10] http://www.heytell.com/front.html
[11] http://www.geochirp.com/
[12] https://foursquare.com/about/new
[13] Example badges are from foursquare http://www.4squarebadges.com/foursquare-badge-list/
[14] http://stackoverflow.com/faq#reputation
[15] http://www.roadintel.com/

The goal of this index is to help motorists gain a better sense of the driving conditions surrounding them in major metropolitan areas.

Future research should design and trial in-car systems that convey and understand social cues/context in order to figure out the impact of such systems on improving collective decision-making. E.g., personalised, individually designed, digital 'boot stickers' could allow public expression towards those sharing the road, conveying cues such as "in a hurry", "relaxing family road trip", "exploring the city", "had a bad/good day", "driving kids to school", "on my way to party", etc. (Figure 4).

Figure 4: Public, social expression on the road



4.2.4 Visualizing degrees of separation

Investigating the *people* layer could provide novel ways to personalise and "humanise" cars. E.g., through the analysis of each driver's social graph, the degrees of separation to each driver can be calculated. An augmented-reality type of application could then display the calculated degrees of separation in a fun way, e.g., through an image to the closest person establishing this link, which would also evoke the strongest emotional response from drivers (Figure 5).

Figure 5: Degrees of separation to surrounding road users

5. Discussion

The following evaluation is based on the assumption that futuristic, highly context aware technologies are available to present the appropriate amount of information at the right time, in the safest and most ergonomic way. It is important to note that the focus in this evaluation is exclusively on the actual data, applications or core concepts (cf. *what?* Figure 2) and not *how* they would be implemented or conveyed. This is a deliberate choice in order to not constrain this research. Nevertheless, the question about the "*how?*" is important and necessary, and is envisaged to follow as the next step.

5.1 Impact on individual level

Research has shown that negative emotion (mood) such as stress or depression can contribute to driver distraction, speeding or other risk taking behaviour or driver aggression. All three are common contributing factors to crashes. The following group of applications can reduce individual stress or anxiety levels:

- POI applications that support finding particular points of interest more easily/automatically, e.g., toilets, petrol stations, vegan restaurants, parking spaces.
- Life organisation, management and automation applications (cf. section *4.1*) automate tasks that the driver has to otherwise carry out manually (e.g., apologising for a late

meeting). This reduces distraction directly, because the manual task does not require to be carried out manually or illegally on a mobile phone. Furthermore, knowing that these tasks are being taken care of provide peace of mind, reduce stress and cognitive load. However, they need to be better integrated and tailored towards their in-car use.

- Applications that support sharing of text, photos or videos amongst drivers can provide more contextual information about the current driving condition, e.g., the cause of being held up by traffic or a construction site or the cause of another driver's behaviour. Knowing the causality of events that impede one's driving reduces the level of uncertainty or anxiety while driving. Furthermore, these media rich communication channels between drivers can also have a more direct benefit on driver distraction: Individuals driving in the opposite direction of an accident are often distracted by the incident, called *rubbernecking.* The curiosity of the incident leads to distraction, which in turn can cause unnecessary breaking, congestion and further accidents. Although a significant part of rubbernecking is attributed to various human factors, there are other factors such as presence of barriers that influence the form of rubbernecking (Masinick & Teng, 2004). Enabling access to rich visual information about the incident through other road users or other road infrastructure systems (e.g., CTV) could therefore reduce distraction through rubbernecking if conveyed in a safe(r) way, e.g., through a head up display.

5.2 Impact on social level

The Intelligent Transport Systems (ITS) research community has carried out extensive research to enable vehicle-to-vehicle (V2V) communication in the future. However, the focus here has been solely on vehicles (machines) communicating with each other, rather than drivers, ignoring the social level. Very little is known about the effects that the ability of this new and better driver communication channels could provide. The possibilities are endless and difficult to predict, similar to how the effects of SMS on the way we communicate today were unpredictable and even unintended.

The lack of being able to communicate or express appropriate social interactions with other drivers more decisively in order to avoid confusion can be a potential underlying factor towards driver frustration and aggression (Deffenbacher, Lynch, Oetting, & Swaim, 2002). Allowing drivers to communicate in better ways could avoid some misunderstandings, but human factors dictate that even richer communication channels can eventually lead to aggression.

Applications that aim towards roads of greater mutual support and peace are worth exploring. However, how can this be achieved? In regards to the rating idea depicted in Figure 3**,** where drivers can collect badges or achievements, the actor-observer bias found in drivers (Baxter, Macrae, Manstead, Stradling, & Parker, 1990) predicts an overwhelming amount of negative ratings, highly subjective and inaccurate. The actor-observer bias refers to the tendency to attribute one's own actions to external causes such as other drivers' behaviour, while attributing other drivers' behaviours to internal causes, e.g., them being an idiot. The hypothesis is that this bias would gradually undermine the goal of this application to promote friendly driving. However, if the application would exclusively focus on positive ratings, e.g., to thank other drivers, there could indeed be a potential benefit. This benefit would probably be strongest within young drivers, especially when combined with motivational gamification techniques or positive peer pressure, e.g., by making these positive achievements available to other drivers or a young driver's social network. Alternatively, the "friendly driving" achievements could be evaluated based on a more objective, unbiased systems rather than other drivers, e.g., hi-tech computer telematics sensing speed, acceleration, breaking, G-force, etc., similar to those found in smart box insurance schemes[16].

[16] e.g., http://www.comparethebox.com/

The limitations associated with subjective, user-generated data also affect the application idea that allows social expression (cf. Figure 4). In Australia, the display of L- and P-plates tell other drivers that one is a learner or on a provisional license. They (more or less accurately) provide clues about the driver's confidence or experience to drive, which in turn can lead to fellow drivers being more considerate towards them. However, L- and P-plates are provided by an unbiased, objective authority. Can user-selected cues have a similar effect to L- and P-plates? Human behaviour is complex and drivers of different ages or backgrounds may react differently to the same information. Furthermore, social exchange is often based on rational choice and cost-benefit analysis (cf. social exchange theory). Assuming that conveying particular cues (e.g., to be "in a hurry") does indeed modify other drivers' behaviour that benefits one's car trip (e.g., giving way more easily), one could hypothesise that based on the cost-benefit analysis, individuals would always choose to be "in a hurry". As a result, this behaviour would gradually undermine the system.

Overall, the social expression application could provide joy in terms of appeasing some drivers' self-importance, but sharing and displaying a self-selected cue to other drivers would probably have little impact on safer driving behaviours, and if it did, the effect would likely to be abused. From a road safety perspective, a more objective, unbiased system would be preferred.

Sitting in today's cars can be an isolating and gloomy experience. Cars appear as machines, lacking any anthropomorphic (human-like) features. This lack has also been shown to contribute towards aggressive, selfish and anti-social driving behaviour (Rakotonirainy, Feller, & Haworth, 2008).

However, triggering a stronger social and emotional connection towards surrounding cars by displaying people we know (cf. Figure 5) needs to be evaluated more carefully. Human relationships are complex and the emotional response from drivers may not always be positive, e.g., if the driver had a recent argument with the person that is being displayed. In a safety context, applications should avoid triggering negative emotions. Further, both, positive and negative emotions can be distracting, so influencing a human's emotions is not only challenging, but may bear unforseen risks. However, one aspect of such an application has a potential safety benefit: reduced anonymity.

Perceived anonymity can contribute towards aggressive driving behaviour. Therefore, applications that aim at slightly reducing the level of anonymity, without breaching the individual's privacy, can have a potential safety benefit.

6. Conclusion

We have only briefly touched upon the potentials benefits of some of the future urban informatics concepts. They need to be further explored and articulated from the road safety perspective. This paper only marks the beginning of this conversation. It raises more questions than it answers, but it raises important questions with a view to invite the road safety community to chime in.

In the immediate future we plan to evaluate these initial results further. Once we have determined a core set of applications building upon the emerging digital layers of the city discussed above (cf. "what" in Figure 1 and Figure 2), we will bring back the discussion to the core of the Auto-UI community, which is *how* (cf. Figure 1 and Figure 2) this information can be displayed or conveyed to city drivers in an intuitive, innovative, convincing, and safe way? The exploration of this question will then inform the development of concrete prototypes that are evaluated within our advanced driving simulator, towards testing some of the hypotheses raised in this paper and towards answering the following questions with appropriate rigour: Which urban informatics data/information could potentially lead to a) an increased joy of driving; and b) an increase of road safety?

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