Eco-efficient feedback technologies:

Which eco-feedback types prefer drivers most?

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Abstract— **Greenhouse gas (GHG) emissions' accumulation in the atmosphere is constantly increasing; since transport sector contributes significantly in rising emissions, substantial action has to be taken, with the support of ICT. Eco-efficient feedback devices, based on smart phone technologies, are becoming more prominent to support and influence drivers to understand their own CO_2 footprint. This paper seeks to evaluate how eco-efficient feedback technologies and which feedback types can contribute to environmental sustainability. In particular, how these technologies can support drivers to achieve more sustainable driving behavior. Feedback types, which influence drivers, are most notably financial savings shown over a longer period and peer reviews.**

Keywords: Eco-efficient feedback technologies, ICT, CO_2 reduction, sustainability, green mobility, persuasive ICT devices, socio-technical.

I. INTRODUCTION

This paper critically analysis aspects how Information Communication Technologies (ICTs) contribute to environmental sustainability and in particular, how eco-feedback technologies can support drivers to achieve more sustainable driving behavior. More specifically, what functionalities and feedback types are relevant, so that users accept them towards an efficient driving behavior, which will become a habitual activity and institutionalized over time.

In order to obtain a socio-technical understanding, it should be studied simultaneously, which eco-feedback technologies influence driving behavior and how users appropriate technology, otherwise the view of the phenomenon would only be technological driven. Therefore, as a theoretical framework the Structurational Model of Technology (SMoT) from [1], was chosen to be able to indicate why and how a given technology is likely to be utilized in a variety of situations, as well as whether this utilization can lead to changes of habits of a particular condition. With the aim to discuss thoroughly on a substantial body of empirical data, a questionnaire survey was initially assembled to investigate drivers' understanding and diffusion of eco-feedback technologies. Then, semi-structured interviews were conducted with drivers who have experience with feedback systems, to enrich insights gained from the first stage of the research.

Key findings of the study indicate that eco-feedback technologies do have a potential to improve sustainable driving, specifically if financial savings are accumulated for a longer period of time and after each drive. Additionally, to understand what could have been saved through a more ecological driving behavior and a comparison with average consumption of other drivers (peer review) is another key influential factor. Technology is by no means deterministic and cannot instill a desirable behavior to users should they do not wish to. Moreover, users ascribe different meanings to similar technologies drawing unconsciously from the notion of interpretive flexibility. Therefore, producers of currently available eco-feedback technologies, which are still in a premature stage, should not only focus on technological advancements but also on aspects of behavioral science to be able to implement feedback types which influence drivers enduring. Although it is early in time to argue about institutionalization of sustainable driving, further research addressing current limitations is recommended.

II. RELATED WORK

A. Types of Driving Behavior and Eco-Driving

Any particular driving style can influence severely fuel consumption and emissions, positively or negatively [2]. A risky driving behavior is mostly characterized by speeding, changing lanes frequently and maneuvering without signaling [3]. Conservative driving behavior is the exact opposite. Aggressive drivers can indicate risky behavior, in addition to expressing bodily or psychological aggression towards drivers, passengers or pedestrians [2]. On the

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contrary, economic driving behavior – also known as hypermiling - has the ultimate goal of consuming the least possible amount of fuel, even by trading off a certain degree of security [4]. Thus, it could not be associated with sustainable driving. Driving styles may result in fluctuations of fuel efficiency, where for example aggressive drivers can have increased fuel consumption by more than 30% [5].

In the literature the notion of reducing fuel consumption as a means of achieving sustainability in driving is widely utilized, which is easily understood and shows tangible results. A recent report from [6] assessed existing technologies that could improve vehicles' fuel economy, targeting the automobile manufacturing industry, it indicated a variety of engine and non-engine technologies that could affect fuel consumption. Moreover, fundamental vehicle characteristics can automatically promote fuel efficiency. Factors affecting fuel consumption include size and external characteristics of the vehicle, engine efficiency and type, transmission type and features, such as radial tires, cruise control and light colors in the external and internal of the vehicle [7]. However, all of these measures require the purchase of a new vehicle considering as many as possible of previously mentioned characteristics, something that could possibly clash with the price one is willing (or able) to pay.

Instead, a rather cost-effective measure applicable to any type of vehicle is eco-driving, which aims at reducing fuel consumption by instilling its principles in everyday driving behavior. If adopted collectively, eco-driving can lead to an average fuel consumption reduction of 5-15%, less greenhouse gas emissions, improved road safety and reduced accident rates thus consisting of a sustainable solution [8]. Therefore, in September 2007 the pan-European ECODRIVEN campaign was launched, in order to help raising awareness of such driving practices [9].

Eco-driving highly depends on individual's behavior, therefore its principles should aim to alter and discourage driving practices that do not conform to these guidelines. One step towards this is to introduce campaigns such as ECODRIVEN to raise awareness, incorporate eco-driving lessons to regular driving training courses or provide additional training. Sadly, even if education is always welcome, it is insufficient to effectively alter driving habits that have become entrenched over years of practice, since drivers tend to return to previous driving behavior soon after training is complete [10]. Eco-driving behavior should be retained mid- and long term instead of vanishing shortly after. Moreover, among the few studies investigating the efficiency of eco-driving, one demonstrated that the majority of drivers who improved their fuel economy were already motivated to do so before training, a fact which appears to have significant influence on reducing fuel consumption [11]. Nonetheless, during and shortly after training drivers indicate maximum results in achieving efficiency, which declines afterwards if not supported continuously [12]. Consequently, more substantial actions are necessary in order to modify an activity that is done automatically, almost unconsciously. Potential interventions include the notion of feedback, regulatory actions, economic incentives, social marketing techniques and ICT to encourage socially desirable behaviors [13].

The next section will focus on the latter, ICT feedback technologies in regards to eco-driving, by introducing initially the beneficiary effects of feedback in improving eco-driving behavior.

B. Types of Feedback in the Automotive Context

[8] suggested that "a device is required that gives the driver immediate and accurate fuel consumption information, yet is not a distraction from safe driving". Among the few studies conducted so far, it was indicated that drivers already motivated to change their driving behavior due to financial reasons, improved their fuel economy by 6% after eco-driving training while driving a vehicle with an on board feedback device providing them with instantaneous fuel information [14]. In a related study conducted in simulator, drivers managed to improve fuel consumption by an additional 7% when driving with a prototype feedback device, providing clear and accurate advice in a screen without posing excessive workload on the driver [15]. The importance of these findings, albeit restricted due to simulation testing, indicate the potential similar systems have [15]. However, until recently quite a small number of mobile eco-feedback devices were introduced for vehicles, whereas even now most feedback implementations are linked to hybrid or electrical vehicles, due to the importance of a specific driving behavior and fuel economy that characterizes the experience of driving these vehicle types [5].

An overview and critical evaluation of current feedback systems follows, attempting to present contemporary automobile related feedback technologies. What should be definitely mentioned is the notion of interaction between vehicle and driver that these systems introduce, by creating an information cycle and attempting to influence driving behavior and performance [16]. Due to the advent and widespread adoption of smartphones, several applications have been developed utilizing the phones' in-built affordances, such as accelerometer and GPS, to provide drivers with real time feedback. Examples of such applications are: Green Gas Saver, greenMeter, BlissTrek, iEcoMeter for the iPhone; Green Driving Gauge, Mileage Genie, Speedometer for the Android operating system.

Figure 1: Cycle of information, [16]

C. Feedback on momentary driving behavior

Information provided to drivers is real-time, by making them aware of momentary driving behavior – e.g. aggressive or smooth acceleration. Awareness is usually created through screen color changes or fuel or CO_2 emissions consumption rates. Systems in this category include Honda's EcoAssist, Nissan's EV LEAF trip computer, Renault's econo-meter, Toyota's Prius Eco-Drive monitor and KIA's EcoDriving system.

Such systems are based on the notion of ambient displays, which are capable of providing feedback information in the mostly unobtrusive manner; user can perceive relevant information through the change of colors even with peripheral vision without much effort and increased cognitive load [17]. Even though from a theoretical perspective this type of feedback should be successful, it was proven that drivers chose to disregard a similar system due to increased mental demand, effort and frustration to achieve desired result; thus, fuel economy was not increased at all [18].

D. Accumulated feedback

Information is aggregated over a longer period of time, ranging from some minutes of the hour to one or more driving cycles. This way, drivers can have an idea of their overall driving behavior and how it may evolve over time. Feedback can be provided either in terms of consumption figures or using schematics, e.g. leaves growing. Through accumulated feedback the notion of rewarding is introduced as well, as the more efficient drivers are, the more advanced figures or schemas they see. Ford's SmartGauge and Honda's EcoGuide are examples of systems that fall into this category.

Based on a similar idea, a prototype mobile tool providing feedback on green transportation habits proved that users perceive positively the thought of accumulated feedback; attention should be drawn to the rewarding nature of the mobile tool, which motivated users to improve their transportation habits and compete with themselves over time [19].

E. Offline Feedback

This type of feedback is decontextualized; overall driving behavior is monitored and then analyzed, in order to provide drivers with a detailed break down of their performance regarding fuel consumption, emissions, acceleration, breaking and gear shifting patterns. Since it is not provided during driving in the vehicle, it can be combined with social networks, where challenges within the online community could improve behavior and goal setting. Such a system is Fiat's eco:Drive.

Social networking is a powerful way of increasing individual participation in social expeditions and in underpinning behavioral advances; thus the contribution of such tools in shaping beliefs and culture, and motivating individuals to improve their driving behavior could be significant. In addition to this, goal setting has been proven to be effective in reducing energy consumption [20]. However, this particular type of feedback relies entirely on drivers' discretion to dedicate extra time after driving for receiving feedback. Yet, it can be used as an additional educative tool.

F. Prior to driving advice

Although it cannot be perceived as feedback in its original meaning, this category includes systems aiming to inform the driver in order to avoid undesired behavior. It is mainly provided in the form of navigation systems where multiple routes are presented to drivers regarding distance, travel time or fuel optimization; thus drivers have the option of selecting the best possible route according to the situation they find themselves into. Examples of this category are Ford's MyTouch and Audi's new generation of navigation systems.

Overall, acceptance of various in-vehicle feedback systems is perceived as positive; however disturbance is regarded a crucial factor, since it can lead to increased risk levels [21]. In fact, during a field test increased cognitive load and stress levels stemming from ineffectual design and position in the dashboard, influenced drivers tend to ignore the feedback system [22].

III. Research Focus

Altogether, the IS discipline can contribute significantly towards achieving environmental sustainability, either by improving existing practices and patterns of human behavior or by contributing to their transformation. Furthermore, the effectiveness of feedback in changing one's behavior is undeniable, especially when augmented through the affordances of modern technology. Despite a substantial body of literature in other areas such as energy savings through smart meters, findings in the driving behavior literature indicate that feedback in combination with willingness to change can result in positive results. The absence of a significant body of literature in the field of mobile eco-efficient feedback technologies does not allow for arguing confidently about the successful results of similar systems.

Since a new generation of on-board systems is emerging – especially after the introduction and progressive adoption of hybrid and electric vehicles – what is relevant to investigate is the potential such systems have towards promoting a change in driving behavior. Specifically, attempting to cover respective gap in the literature, the scope of this paper is to clarify how eco-efficient feedback technologies in general contribute to environmental sustainability and in particular to unfold how feedback technologies can influence drivers towards achieving a sustainable driving behavior; what functionalities are more relevant and how users utilize them in accomplishing an eco-driving behavior, which will be sustained and institutionalized over time.

IV. Theoretical Lens

The Structurational Model of Technology (SMoT) from [1] was chosen as a theoretical framework to indicate why and how a given technology is likely to be utilized in a variety of situations, as well as whether this utilization can lead to changes of habits of a particular condition.

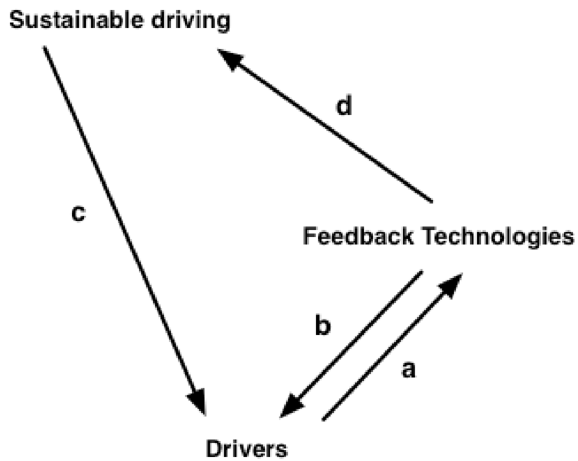

Figure 2 Structurational Model of Technology, adapted to sustainable driving

The SMoT from [1] comprises three constituent elements; human agents, technology and institutional properties of the social context that the previous two find themselves into, while it is concerned with their interplay and its influence on each (component). Initially, technology is a product of human action (arrow a), meaning that after its design and development, technology only comes into existence when appropriated and enacted by users, ascribing to it a variety of meanings and reinforcing its notion of interpretive flexibility. In turn, technology as a medium of human action (arrow b) enables and simultaneously restricts the outcome of human practices through its affordances, thus shaping it according to the rules and resources that are inscribed in it. Its modifying ability is mainly determined by designers' intentions, institutional setting into which technology is utilized and users' ability to act otherwise. When acting on technology – in whichever way – human agents are influenced by the institutional properties of their setting (arrow c), drawing on existing stocks of knowledge, resources and norms to perform their work, whereas situated human action implies that it will also be shaped by the immediate context it takes place. Accordingly, human interaction with technology may reinforce or change the institutional properties of the setting (arrow d).

As a lens, the adoption of a specific theory may allow investigating specific phenomena, while simultaneously obstructing the perception of others. For example, SMoT does not investigate the direct impact of human agency on institutional properties; assuming that only through interaction with technology institutional settings may be reinforced or changed cannot be universally correct. Choosing an alternative theory could also promote different concepts; e.g. Technology Acceptance Model (TAM) [23] might explain why drivers would adopt or ignore feedback technologies, but it would not be able to explain if a change in their driving behavior would happen. SMoT is mostly concerned with why and how a given technology is likely to be appropriated in a variety of situations, thus it is more suitable for application on given feedback technologies as embodied structures and their influence on driving behavior [24].

V. Research Methodology and Design

As this paper is addressing issues regarding individuals' interaction with technology, appropriate modes of approaching the object of study include field experiments, case studies, surveys, simulations, game role playing, and interpretive approaches. The research design was based on a sequential multi-method approach, with different types of methods utilized in sequential order and results from one level fed to the next [25]. More specifically, an on-line based questionnaire survey was used as springboard to gain a substantial understanding of respondents' overall knowledge and disposition regarding feedback technologies. The questionnaire was followed by in-depth semi-structured interviews of drivers who had experience of similar systems while driving, where the researcher attempted to conceive the main reasons behind their responses, as well as the impact of such technologies in their driving style. Since interpretive studies are not necessarily restricted to qualitative methods, quantitative data resulting from surveys can also serve as valid sources complementing interviews [12]. In fact, limitations from one type of research method can be addressed and compensated by using an alternative one.

The online survey had an explanatory initial page, to introduce the respondents to the area of research and allow them to familiarize with basic concepts. Respondents were also asked to rate different types of feedback according to their preferences, in addition to justifying their choices. Open-ended questions next to of multiple-choice allowed respondents to express themselves freely and elicit their pure insights without any biases from pre-determined options. Respondents for the on-line questionnaire survey were mainly accrued through the researchers' social networks, by circulating it through mail and various social networking services. In order to increase the response rate, snowball sampling [26] was also adopted; respondents who had already answered the questionnaire, forwarded it to people from their network.

Regarding the drivers interviewed, the main criterion was to have previous experience with feedback systems while driving and being able to comment on their experiences and personal opinions. The majority of them where chosen through the on-line questionnaire survey, as they were asked to provide contact details for further questions. Altogether, eight in depth interviews were conducted, lasting for about 45 minutes per interview.

VI. Findings and Discussion of Empirical Data

A. *On-line survey*

The on-line survey was used as an initial step in the research, in order to gain insights of drivers' understanding and disposition towards such systems. In total, 539 respondents answered the survey, aged from 18 to 50 years old. The majority stated that it has less than 20 years of driving experience (71.23%) and that they usually drive every day (57.55%).

When asked whether they were aware of feedback devices aiming to improve one's driving behavior, two out of three (68.66%) answered positive, with the greater part (40.71%) being familiar with navigation systems. Other popular options were trip computers (28.32%), on-board gauges (25.22%) and smart phone applications (14.6%). Half of the respondents indicated that they have already used any of the above mentioned systems while driving, with almost 70% of those mentioning that they noticed a change in the way they drove. This suggests that the diffusion of feedback technologies is about to start spreading among the late majority of drivers as well [27]. Furthermore, the vast majority (84.85%) of those who had no previous experience with similar systems, also believed that it could affect their driving behavior towards becoming more efficient, demonstrating a positive disposition towards feedback technologies.

Introductory questions aimed at familiarizing respondents with the topic of research, whereas the next section of the questionnaire went into more detail, asking them to specify what type of information they would prefer to see in a feedback system. Eight variations were presented, which respondents had to evaluate according to their preference in a 5 point likert-type scale with 1 as most preferable and 5 as least preferable. The findings indicated that respondents would rather see information about personal fuel consumption than anything else, awarding it with 1.53 points, followed by potential savings that could have been achieved through a more efficient driving behavior, which was rated with 1.98. Other important aspects were the comparison with other drivers (1.7) and their average consumption for the same distance or duration of driving (1.99). What seemed to leave them relatively indifferent was a rewarding scheme when achieving an efficient driving behavior (2.97). Furthermore, as most important was considered to receive information during driving (2.03) or immediately after (2.3), whereas information before driving in the type of advice was not considered so relevant (2.77). Last but not least, most preferable channel of communication was considered to be either visual (51.67%) or the combination of visual and audial (42.78%); information provided only audibly was not regarded as much relevant (5.56%).

In the last section of the questionnaire, respondents were asked to rank six different feedback systems already available in the market, according to the order of their preference. Systems introduced to them were representatives of different types of feedback discussed previously, consisting of four on-board solutions and two mobile applications. Most preferred was nominated a dashboard screen changing colors to inform on momentary driving behavior, whereas least preferable was a computer application providing offline feedback by analyzing driving data. Dominant reason for choosing the most preferable system, according to respondents' explanations, was the way information was communicated to them; momentary feedback provided in an easily understandable and unobtrusive manner, requiring the least possible attention while driving and not hindering safety, which is a crucial issue. This agrees with the introduction of ambient displays as feedback mechanisms [17]. Aesthetics proved to be an important reason as well. Absence of real time feedback, decontextual information, additional effort required and inconvenience were mentioned as key reasons for appointing the computer application as the least preferred one.

B. Interviews

This part attempts to present and interpret key findings of the interviews in light of the structurational model of technology. Main purpose was to unveil interplays between constituting elements of the model (see Figure 2). In this case drivers, feedback technologies and sustainable driving, in order to analyze them according to the theoretical premises of the conceptual framework.

Even though interpretive flexibility of technology is bounded to material limitations, institutional context and knowledge, power and interests of users, empirical data indicated a wide range of cognitive perceptions and definitions drivers assigned to feedback technologies. For example, for some it was a means of quantifying the efficiency of their driving (Person 1, Person 7) or a trigger, able to make them think about their efficiency (Person 5) and "… fuel and money you are burning" (Person 3). For Person 7 it was "… like a cigarette pack with bad pictures… It can give you bad feelings and make you guilty about consuming a lot", whereas for Person 4 it represented a sort of rewarding scheme, fulfilling the goal of a similar system's designers aiming to create a system able to inform and reward drivers simultaneously [16]. Alternatively, it can have a symbolic meaning, representing "modern technology" (Person 6) or installing the idea of competition with other users of the car (Person 2) which can have positive effects on reducing energy use [28]. The variety of meanings interviewees attributed to feedback technologies is rather surprising, given the fact that feedback systems installed in vehicles allow for minimum customization (Person 5), drivers rarely have any involvement in their development and are associated only with the activity of driving. Furthermore, it should be also mentioned that three interviewees (Person 2, Person 3, Person 6) presented the feedback system in their vehicle differently and seemed to ascribe different meanings to it, even though they were referring to the exact same vehicle.

The majority of respondents agreed that by glancing at the feedback mechanism integrated in their dashboard, they could understand immediately fuel consumption levels; they could then choose to act accordingly and reduce it or ignore it (Person 6). However, even though drivers can get a better understanding of their driving efficiency, they do not receive any advice on how to improve it (Person 3), which has been proven to have positive effects [15]. An interviewee stated explicitly "… as long as they don't intervene to your freedom as a driver" (Person 5) implying that feedback technologies should not attempt to impose any sort of power or immediate control to users by restricting their actions. Available functionalities allowed only for a specific representation of information, instead of allowing them to have more options and provide customization (Person 5). Furthermore, older drivers would possibly face issues when interacting with such technologies, either because of increased workload or because aged users are usually not comfortable with sophisticated technology (Person 4). Questionnaire results indicated that half of the respondents were not aware of carbon emissions meaning; once they were displayed their equivalents to everyday activities, they found them relevant to improving their driving efficiency. An interviewee also mentioned when prompted that the feedback he received in the form of CO_2 emissions amount had absolutely no impact on him, since he wasn't aware of it's significance (Person 6), proving that artifacts are unable to inform users' practices if they are unaware of their functionalities and their meanings [29].

Context and its institutional properties influences human agents when they interact with technology. Awareness levels regarding climate change and environmental sustainability are raised in the past years, leading to increased attention of fuel consumption rates (Person 2, Person 3, Person 7). However, another major reason influencing drivers is financial impacts of consuming excessive fuel. As fuel prices have increased the last few years, respondents mentioned that it had a clear and direct impact on their driving behavior (Person 4, Person 5). More specifically, "… it was mainly the fuel price that persuaded me" referring to a change in his driving behavior (Person 4), in agreement with studies indicating that motivated users with financial incentives were more successful in reducing their fuel consumption ([11], [14]).

Furthermore, drivers appear to be influenced by the immediate conditions where they drive to, revealing that these are actually reasons whether feedback technologies are used or not. Regarding city center navigation, respondents mentioned that they did not pay too much attention on their driving behavior or feedback systems (Person 1, Person 2, Person 8); [14]). For example, Person 1 said: "During rush hour I was paying more attention to the road and didn't care too much how I was driving", in agreement with [18], where drivers ignored the feedback system due to increased stress.

Respondents admitted that when paying attention to the feedback system it helped them to achieve lower fuel consumption and a more efficient driving behavior (Person 1, Person 2, Person 6). More specifically, one acknowledged the change of habit after using feedback technologies his vehicle (Person 6). Disrupted interaction with feedback technologies due to demanding driving situations or anxiety to reach quickly their destination can nonetheless undermine institutionalization of sustainable driving, as the more time drivers spend under those conditions, the more they will depart from it. Moreover, they implied that they already know which driving behavior is efficient and which not, but the fact that they were able to see the traffic situation was very influencing to drive more or less ecological (Person 2, Person 4). It should also be noted that due to relatively limited fuel savings from adopting an efficient driving behavior [30], drivers may feel that the extra effort required might not be of worth, contradicting the case of feedback devices for domestic energy consumption, which met acceptance by users and increased energy savings ([28]; [17]; [31]).

When drivers attempt to adopt their driving behavior to what feedback technologies instruct – e.g. when they see high consumption rates, less leaves or red LEDs on according to respondents' description – they actually adhere to sustainable driving, while the knowledge and assumptions of sustainable driving embedded to feedback technologies regarding the particular vehicle are transferred to them. Thus, feedback technologies serve as interpretive schemes, allowing them to understand whether they are driving efficiently or not.

By using feedback technologies, drivers act according to their assumptions regarding sustainable driving; by doing so, they accept the power imposed to them through the facilities feedback technologies offer. However, when ignoring the system, domination is bypassed and sustainable driving is undermined. This constant fluctuation between accepting or ignoring the control imposed to them indicates however, that the adoption and unconditional use of feedback technologies has not been institutionalized yet and drivers do not consider them as part of their driving behavior.

Lastly, sustainable driving is understood by low consumption and emission rates, leaves, green LEDs on, electric mode powering the vehicle; thus, feedback technologies can reproduce norms of sustainable driving, which will govern the activity of driving. Furthermore, feedback technologies should be part of the sole legitimate manner of driving. This has been already achieved to a certain point, since hybrid and electric vehicles have integrated similar technologies in their dashboard, as shown by currently available feedback technologies in the automotive market. Since driving behavior is of greatest importance in these vehicles [5], they should emphasize on indicating energy levels available and the impact of driving behavior to them.

VII. Recommendations

Summarizing, one could argue that feedback technologies alone are not able to enforce sustainable driving behavior, since even highly sophisticated feedback systems will be of no value if drivers ignore them or are unaware of their indications. Similarly, behavioral approaches such as eco-driving will not suffice either, as drivers utilize feedback technologies to quantify their efficiency and boost their performance. Proper interaction in a socio-technical level is thus necessary, with elements supporting and complementing each other. Yet, to achieve maximum results, interaction between drivers and feedback technologies must be guided properly [20]. The interaction on the socio-technical level is also influenced by institutional properties in which drivers live, in addition to their immediate environment.

Consequently, automotive industry should enhance and promote the notion of interaction cultivated between feedback technologies and drivers, firstly by developing unobtrusive systems, not posing additional workload and frustration to drivers and being seamlessly interweaved into driving. Another suggestion is fully customizable systems, so drivers can adapt them according to their individual, momentary preferences and needs for provision of completely personalized feedback, increasing in that way the possibility of engagement and fruitful interaction with the system. Available options could include, but not be limited to different types information provided or periods of feedback. Previous remarks should be taken in account when manufacturing various types of systems aiming to promote sustainability, as by taking into consideration immediate context and providing options for personalization likelihood to engage users more actively and yield optimal results are increased.

VIII. Conclusion

Since the accumulation of GHG emissions in the atmosphere is steadily rising, ICT should characterize the promotion of sustainability [32], especially in personal transportation domain, among the main contributors of CO_2 emissions [30]. With the aid of Structurational Model of Technology (SMoT) by [1], empirical data collected through a questionnaire survey and semi-structured interviews yielded the following key findings.

Most preferable were unobtrusive feedback systems, able to convey clear and contextual information. Furthermore, drivers ascribe various meanings to feedback technologies, which can mediate understanding and quantification of driving efficiency. Limited options not serving drivers' specific preferences and situated needs is a disadvantage that next generation feedback technologies should address. Social and historical conditions such as technological advances and increased ubiquity of novel technologies, environmental discourse and interest for ICT solutions for green mobility, environmental awareness and financial concerns of individuals along with driving conditions and situations drivers navigate into, are all factors influencing interaction with feedback technologies. Feedback technologies also seem to reinforce the institutionalization process of sustainable driving; however, highly situated activity of driving and attention requirements do not allow for continuous appliance and interaction with technology, necessary to achieve a behavioral change in ecological driving.

In general though, interaction and adaptation of driving behavior will be more than necessary in case of hybrid and electric vehicles, since it increases vehicles' range without additional charging required; interaction between drivers and feedback technologies must therefore be guided appropriately to achieve maximum results and efficiency [20]. Additional measures should also be taken to reinforce improvements of environmental conditions by further education in the field of eco-driving to change human behavior and perceptions towards a more eco-friendly driving behavior.

IX. Limitations

The absence of significant debate throughout the study is due to limited literature, since this is a recent field of investigation and most studies were concerned with implementing feedback systems instead of observing the practice and outcome of users' interaction over long period of time. Most important limitations in the theoretical domain were the high-level nature of the conceptual framework yielding results mainly in a macro level; time barriers however only allowed for a static snapshot of the situation instead of investigating patterns of use evolving over time.

Methodologically, the main challenge was putting the theory into practice, since it does not prescribe how research should be conducted, which was overcome with extensive study of theoretical concepts and insights from fellow researchers on how to better apply it. Apart from that, shortcomings of surveys were compensated through semi-structured interviews.

X. Further Research

Naturally, alternative theories would introduce different insights on the same phenomenon as probably would do another demonstration of the theory into practice. In order to further promote knowledge in this field, further research should also include observation of drivers for a substantial period of time, to generate robust results and insights on how drivers interact with feedback technologies, including how this interaction evolves over time. Additional suggestions comprise a larger sample size across various demographic groups and use of the exact same technology to facilitate an in-depth analysis of different perceptions and meanings drivers may ascribe to feedback technologies. Therefore, a combination or even all of the previously mentioned recommendations should provide adequate supplementary knowledge in an under-researched area of eco-efficient feedback technologies.

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