Instances of Failures, Maintenance, and Repair in Smart Driving

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Abstract: The paper focuses on technology designers' representations and discourses about advanced driving assistance systems (ADAS). This issue has been empirically explored by means of seven in-depth interviews with academic experts in intelligent transportation systems (ITS). Two main areas are investigated: 1) the meaning of advanced driver assistance and 2) the failures in intelligent driving and the consequent need to cope with them. The overall aim is to identify dominant views about the instances of "failing" and the possibilities for control, which are inscribed in the design processes of ADAS. One of the main findings concerns the designers' emphasis on the continuous supervising, correction, and enhancement of human functioning as the core of driver assistance. According to this view, human senses, reactions and interactivity with technology turn into subjects of continuous supervision, prevention, correction, improvement and restriction – a sort of "real-time human maintenance and repair".

Keywords: intelligent technology; advanced driver assistance; driver monitoring; human-machine co-agency; automobilities.

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1. Introduction

The usual perspective about maintenance and repair of conventional technology (i.e. which does not carry the labels "smart", "advanced", or "intelligent") is that humans in various roles are the only ones able to check its functionality, to observe and fix eventual failures. The internal elements, motions and operations in such technical systems are easily visible and the relationship cause–effect for faults and failures is quite clear. Therefore, conventional technology can be easily dismantled into comprehensible pieces, which can be re-assembled for new purposes. In this view the malfunctioning of various infrastructures contains the germ of

T/S TECNOSCIENZA
Italian Journal of Science & Technology Studies

innovation in its core (Graham and Thrift 2007; Jackson 2014). The necessity to fit the technological systems "to the sticky realities" (Jackson 2014, 227) of the real-world driving, living, working, communicating, etc. should in principle encourage the involved actors (users, technology designers) to improvise and come with sometimes unconventional, but reality-friendly solutions.

However, in "advanced technologies" such as ITS (intelligent transportation systems) the humans confront with a much higher complexity, a hidden autonomous activity, and a high interactivity of technology (Rammert and Schulz-Schaeffer 2002). In-and-out sensors embedded in vehicles and road infrastructures perceive changes in the environment. Data from various sources are then processed and turned into integrated information, which is further provided to human users through user interfaces. Advanced technologies operate in "intelligent spaces" that are "environments that continuously monitor what's happening in them, communicate with their inhabitants and neighbourhoods, make related decisions, and act on these decisions" (Wang et al. 2006, 68-69). Such systems pretend to be active to the extent that they even seize their own repair and maintenance in a process of "self-healing" (Graham and Thrift 2007). The self-supervision of functionality, automatic fault detection/diagnosis, and self-repair are currently established abilities of advanced technologies. The current paper proposes a perspective on "maintenance in repair" according to which technology designers of advanced driver assistance systems increasingly see humans as possible subjects of failures and breakdowns. In this vision drivers should be constantly supervised and restored to functionality if they become fatigued, stressed, distracted or show signs of health deterioration. This perspective is explored by means of interviews with experts working in the field of Intelligent Transportation Systems and completed by a brief review of the technological state-of-the-art.

The present article is structured in five parts. The first part is dedicated to the introductory analysis of the current perspectives on maintenance and repair. This is followed by the presentation of designers' scripts on ADAS and further developments such as vehicle automation, based on the study of the field literature. The paper continues with the description of the methodology of the qualitative study and the presentation of results. The last part is dedicated to the discussion of the empirical findings and the directions for future research.

2. Perspectives on Maintenance and Repair in Hybrid Systems

Despite the fact that maintenance and repair are considered central issues for the understanding of modern societies, they have been so far insufficiently studied and understood (Graham and Thrift 2007). Nevertheless, their importance comes clearly to light when their disruptive effects manifest in economy and society. Let's only mention the impact of cell phone disconnection on healthcare and health (Gonzales et al. 2014), the nightmare of electricity and IT systems blackouts, or the failing of traffic signalization in a big city. As Graham und Thrift (2007) emphasize: "Things only come into visible focus as things when they become inoperable- they break and stutter and they then become the object of attention. Such disconnection produces learning, adaption and improvisation" (Graham and Thrift 2007, 5).

The social sciences literature comes with various perspectives about the concepts of maintenance and repair. For Graham and Thrift (2007) the importance of maintenance and repair is justified by some particularities of material things such as: intrinsic power (things are "transductions with many conditions of possibility and their own form of intentionality"), pluriculturality, increase in number and complexity (fact that requires even more maintenance and repair), the difficulty to define the border of "things" (they could represent more than supposed). It is also emphasized that: "Breakdowns come to have an essential quality to them, since they may well affect large numbers of people simultaneously" (Graham and Thrift 2007). Ureta follows Foucault in defining repair as: "a particular form of power that, first, recognizes a certain normal state to which the failing system should evolve and, second, develops different strategies to reach it, usually involving the deployment of particular disciplinary devices. The ultimate aim of such practices is usually not only the improvement of the system but centrally the maintenance of a certain kind of power" (Ureta 2014, 368). The Human and Computer Interaction branch sees repairs as: "acts of sustaining, managing, and repurposing to cope with attrition and regressive change", advocating for its high importance in design of ICTs (Rosner et al. 2013).

The research on maintenance and repair has focused, amongst others, on the unification of the social and material in urban cities as social systems for maintenance and repair (Graham and Thrift 2007; Hall and Smith 2015), the "remediation work" in the travel sector as response to terrorist attacks (Ball et al. 2014), the repair of failing large sociotechnical systems (Ureta 2014), the vulnerability of systems enacted in repair and maintenance practices as a dimension of material ordering processes and care for things (Denis and Pontille 2015), the improvisation and creativity resulting from the possibility to dissemble technology, attending of consumer objects within the home (Gregson et al. 2009)[1].

In the "tightly drawn" infrastructural networks (Graham and Thrift, 2007) of the present, the distinction between things and human actions is

[1] For a review of studies on repair and maintenance from the perspective of Human computer Interaction (HCI) in connection with a CHI workshop on this topic see Rosner et al. (2013).

blurred and hybrid constructs emerge. The driver-car represents such an assembled social being that depicts the properties of both sides (Dant 2004; Urry 2006). As of lately, intelligent transportation systems (ITS) have grown into a spinal socio-technical cord of human-machine activities integrating movement, communication, and information into a complex structure. More than being a good illustration for actor-network theory (Graham and Thrift 2007), the mix of bodies and machines in the current advanced technological systems puts new challenges to the study of maintenance and repair.

One of the most important challenges regards the blurring of agency fields of humans and technologies. Pervasive technologies are in general subject of confusing accountability of agency: "in many instances we are unable (from an outside point of view) to distinguish human action from non-human action, because the system's behavior is almost identical" (Weyer 2005, 10). If we take the example of modern aviation, both human and non-human elements could be involved in failures and system breakdowns to various degrees, as well as in the activities of maintenance and repair. The causes of aviation accidents combine "pitfalls of automation, organizational failure, insufficient training of humans, as well as divergent safety cultures and unresolvable conflict" (Weyer 2006). It is extremely difficult to determine a "decisive" contribution of one or other of these causes to accidents, because the responsibilities and actions of technology and humans are widely distributed (Weyer 2006a). In this distributive constellation, one core responsibility of the advanced technology (in ADAS, cockpit automation, Smart Homes, etc.) is to achieve the control of the environment also through the intensive supervision of technological and human functionality. In the context of generalized monitoring the supervised humans may be prevented from acting strategically and from learning from past failures because: "they try to avoid situations in which the individual can fail (and learn) – by presenting or rather constructing a "perfect" world, that shows up according to the system's rules, the user does neither know nor understand."(Weyer 2005, 7). The logic of intelligent systems is the "preventive avoidance of learning (by doing or by experience)" (id.).

Against this background, failures and repair in hybrid systems in which artificial agents and humans interact and act together (Weyer 2006b) represent complex topics that need to be addressed more in detail by the research dedicated on maintenance and repair. There is still need for research about the contexts and possibilities and failing in such systems, the accountability for this (who/what acts, who/what is responsible for the consequences of maintenance and repair), and the solving possibilities.

3. Technological Scripts of Driver Assistance: from Advanced Driver Assistance to Driverless Cars

The current assistance in ADAS (advanced driver assistance systems) ranges from information providing (navigation systems, Traffic Master and RDS-TMC receivers), feed-back with the intention of reducing drivers errors and traffic violations (longitudinal collision warning systems, lane departure warning systems and lane-change assistant systems) to intervention in vehicle control without completely supplanting the driver such as intelligent speed adaptation, Adaptive Cruise control, Stop and Go (Carsten and Nilsson 2001).

The strongest motivation for the development of solutions for driver assistance is the enhancement of traffic safety. Traffic safety research has generally established that static characteristics such as age, gender, cognitive and motoric internal characteristics, level of experience, influence the way in which drivers behave on the road (Evans 2004; Shinar 2007). Some categories seem to carry the "unsafety" germ in their core, such as: "the adolescent driver" (Glendon 2011), "old drivers" (Schultheis and Manning 2011), males, among them particularly the "the sensation-seeking" ones (Rosenbloom and Wolf 2002). The youngest drivers seem to manifest a tendency for risk taking and immediate rewards, have a rather irrational, disorganized thought pattern and manifest a delayed processing of critical information about generically dangerous situations (Glendon 2011).

The focus of traffic safety research has been placed also on the negative effects of dynamic states such as inattentiveness and sleepiness/drowsiness (Evans 2004). In the last times there have been growing efforts to detect such dynamic drivers' states, which resulted in various driver monitoring systems to monitor sleepiness, drowsiness, distraction, or inattentiveness on the road (Wang et al. 2007; Rogado et al. 2009; Park et al. 2011; Regan and Hallett 2011). Volvo has developed a fatigue monitoring system based on a sensor anchored in the instrument panel that registers the direction in which the driver looks, how far his eyes are open and how he or she holds her head. If fatigue signs are detected, the car increases the distance to the car ahead as a precautionary measure and warns the driver. Such system should also be able to warn drivers before nodding off. Technical solutions are developed according to "scripts" described by Akrich (1992) as: "the end-product of the designers' hypotheses and visions about the entities that make up the world into which the object is inserted" (Akrich 1992, 207-208). As the literature on advanced driving assistance systems and particularly monitoring systems shows, the dominant representations of technology developers about driving are populated by dangers that can be intelligently detected and prevented through the in-advance recognition of some "bad or dangerous" characteristics of the involved elements.

This smart recognition should enable the warning of drivers (and thus the correction of their behavior). Technology should even take over the control when humans are not able to control the vehicle anymore. In the last time, in parallel to the efforts for a better understanding of the drivers' behaviours, there are significant efforts to further decrease the arbitrariness of human actions by means of autonomous driving. The vision of driverless cars has been lately enthusiastically adopted by the many engineers working in the ITS field, as the recent ITS IEEE conferences testify. A true "revolution" in vehicle automation is expected, made possible by the low-cost sophisticated sensors (Denaro, 2013). Ideally, the autonomous driving should bring liberation from the strains of driving, a better employment of humans' mobility time, and a higher in-car comfort. The concrete realization of this vision has technical, as well as human and social requirements and paths of action. From the technical point of view the road towards the establishment of automated driving systems is marked by implementations such as: automatic gears and power steering, servo systems open windows, roof lights, sensor-based monitoring system that adjusts the heat inside and responds to the outside environments by switching wipers and lights on and off, anti-lock brakes and devices that control suspension and over-steering. (Laurier and Dant 2011).

Recently DIBOX implements the vision of smart cars communicating with drivers and answering to questions such as: Have I lock up the car? Should I refuel the car today? How much time do I spend in the car? How I have driven in the last time? Other developments are Adaptive Cruise Control (ACC) and platooning (cars driving automatically a row with short spacings between them). Also the field of Cooperative Traffic Systems features pilot projects with corresponding policy recommendations. In the project Drive Me[2] (2014-2017) self-driving cars will ride on about 50 km of selected roads in and around Gothenburg. This will be made possible by the cooperative traffic technology that enables the interaction between vehicles and street infrastructure. The control of the road and traffic is combined with that of the driver. The official homepage of the project highlights some individual benefits for drivers that should derive from the mix of autonomous and active driving:

> Autonomous driving will fundamentally change the way we look at driving cars, as you can plan your drive with a mix of autonomous and active driving. This makes the journey more time-efficient. You can safely interact via phone or tablets or simply choose to relax. The self-driving technology used in the pilot allows you to hand over the driving to the car when the

[2] The pilot project will be conducted von Volvo Car Group in cooperation with the Swedish Transport Administration, the Swedish Transport Administration, the Swedish Transport Agency, Lindholmen Science Park, and the city of Gothenburg: www.multivu.com/mnr/64153-volvo-self-driving-cars-unique-swedish-project (last access: 28/10/2015).

circumstances are appropriate comments. (Håkan Samuelsson, CEO of Volvo)

The google car project has recently (2014) allowed reporters from Spiegel to act as test passengers through the dense traffic in Silicon Valley. Their most striking feeling was that the driverless car had not behaved in the fluent traffic differently from other cars: "The car accelerates and brakes smoothly, changes lines as it should, stops at zebra crossings for pedestrians, avoids cyclists, and follows a modified traffic routing at a construction site" (Schulz 2014). The autonomous driving mainly challenges the possibilities for human agency and the perspective of driving as an activity accomplished with others (Laurier and Dant 2011, 228). Technology designers expect that the task of driving disappears, as cars turn into uncoupled small train carriages – a new hybrid form of car-train assemblage (Laurier and Dant, 2011). As Thrift emphasizes: "what is thought to be a mature technology is currently changing and transmitting into quite different by an oblique route" (Thrift, 2004, 48). Autonomous technology should in principle make the traffic more predictable and faultless, as "driverless cars will follow the rules, abide by speed limits, and stop at stop signs without growing bored, tired or resistant of doing so"(Laurier and Dant 2011, 239). However, perverse effects concerning the objective of the reduction of congestion may appear, since the attractiveness of driverless cars will bring more vehicles on the road (ivi). The variety of emotionally charged actions in which drivers and passengers are currently involved while inhabiting the car: story-telling, learning, planning, complaints, mundane economica (Laurier and Dant 2011, 229) might be reduced through automation. Distraction and fatigue as important sources of road accidents should be eliminated. Vehicle automation could lead to less social interaction between humans and more concentration on "insular activities such as reading or working on computer"(Laurier and Dant, 2011, 237), relaxation and entertainment. However, for the present moment, the ITS community emphasize that "autonomous driving" or "automated vehicles" should not be made equal to "driverless" since drivers should remain an important part of the system. As the own observation of conference presentations and informal discussions at the IEEE ICTS2013 has confirmed, the designers' community believes that drivers should not be alienated from driving and be relieved from the responsibility for the driving process. The future inhabitants of automatic cars should retain the responsibility for the consequences of driving (for regulatory reasons, industry interests). A new dilemma occurs for this transition phase: how reach and maintain both driver inclusion and exclusion in driving a semi-autonomous car? It can be observed that the visions of the community of technology designers about how to assist humans in their mobility are not without tensions and contradictions. The inclusion and exclusion of humans from driving activities has to be sometimes implemented in the same wave of technology development, as the future development of driver awareness solutions in semi-automated cars will show. In this vision, the role of drivers will be rather that of “watching absents”, who are allowed to work, read, play and sleep, while also keeping their eyes on the machine controls and the road. The monitored humans will still have to monitor the technology.

4. The Empirical Study

4.1. Methodology

Adopting a phenomenological approach based on qualitative methods, the main objectives of the research in the current paper are to analyze how designers’ scripts about advanced driver assistance relate to the topic of failures, maintenance and repair in intelligent driving. The working hypothesis of the empirical study is that technology designers regard failures and breakdowns in traffic as mainly deriving from human behaviour. They are open therefore to a necessary monitoring of human drivers that is necessary to make up a world of “safe and pleasant mobility”.

Seven interviews were conducted in 2014 with academic researchers working in the field of ITS research and development in Austria, region of Carinthia. Their main area of expertise is advanced driver assistance systems, road traffic signals, and driver and driving monitoring. All interviewed persons were males, aged from 25 to 46 years. Their experience in the field ranges from 2-3 years to more than 20 years (2 persons). In spite of the recognized importance of gender issue for the analysis of technology scripts (Oudshoorn et al. 2004), due to local circumstances it was not possible to include female experts in the study. The results have to be therefore interpreted in terms of technological scripts of male designers about driver assistance. The interview partners were approached face-to-face and informed that the study aimed at exploring their attitudes about the new developments in the field of intelligent vehicles, driver assistance and vehicle automation.

An interview guideline has been developed on the basis of the operationalization of the concepts. The perspective on the assistance of drivers adopted in the study relies on the combination of three dimensions: support of safety (either by actively supporting the driving task, or passively supporting the car itself), information (traffic or situational information, such as navigation and traffic information receivers), and support of entertainment and car environment (video, music and multimedia, light and temperature). Failures and breakdowns have been explored in these areas, with a particular focus on the safety dimension. During the questioning of the meanings of driver assistance no definition of concepts or dimensions has been previously given to the interview partners. The objective was to obtain spontaneous wordings, representations, and examples.

Although the interview participants were encouraged to freely follow spontaneous ideas as they had appeared, special attention was paid to the following topics:

— General cognitions and attitudes about ITS and ADAS;
— The role and intervention powers of humans/technology in intelligent driving;
— The meaning of driver assistance with examples;
— Types of failures in the ADAS supported driving. Coping with failure and breakdowns;
— Attitudes towards driving automation.

The interviews were audio-recorded. The length of expert interviews was between 45 minutes and 1 ½ hours. Five interviews were conducted in English and two in German (translated afterwards by the interviewer).

4.2. Results

4.2.1. Background Representations of Advanced Driver Assistance

The experts' representations about driver assistance technologies provide the interpretation background for the section dedicated to the failures of human and technological elements and the coping with this. The main goal of the analysis has been to establish how advanced technologies are supposed to support humans by means of semi-autonomous actions and human-machine communication, particularly in the case of incongruence between driving goals and actual behaviour, at the strategic, tactic and operational levels.

The meaning of driver assistance enjoying highest consensus among technology developers is synthesized by the expert 7 as: "the support of human perception; reasoning, and action (support to drive)". Related to perception, expert 7 stresses the importance of issues such as the range of perception and its reliability. Sensors can represent here a key problem, because they can break down, or have a low reliability. The resulting perception can be not good enough or fail in particular conditions such as rain, night vision or fog. Driver assistance is understood also as a necessary extension of drivers' powers and senses, not only in what concerns the provision of night vision or dead angle visualization but also related to their fluent integration in the traffic flow:

> for example the system can warn you that if you still drive that speed you will reach red light and you slow down a little bit you will be green and so on…so it can make the traffic flow to make it more fluent. (Expert 3)

A good perception provides the basis for the best reasoning about what to do in a given driving situation. The particular emphasis in the support of human reasoning lies on the transforming of real-time driving data into information useful for drivers. As Expert 6 maintained, “driver assistance is about providing information in correct time to help the user make the right ‘correct’ decision”. Last but not the least, it is expected that the assistive technology improves the adequacy of human actions to the challenges of the driving context and also enhances the rapidity of manoeuvres. This is because human reactions are slow compared to automated actions. In addition, if the driver is tired his/her attention decreases and wrong manoeuvres are performed and good manoeuvres may be disregarded.

During the interviewing process I have become aware of a strong apprehension of the experts about humans as dangers in traffic. As spontaneously emphasized by expert 7, the current state-of-the-art cars are very reliable and predictable. On the contrary 90% of the problems in traffic appear due to the human component, therefore the necessity to monitor what happens to the human driver over short periods of driving. Expert 2 generally agrees with the necessity of “automating” human processes and minimizing human errors:

> I believe that wherever people work, there are dangers and problems. I believe that the traffic and the technology has become so complex, so many areas are loaded with dangers and problems that such risks and potential dangers are getting bigger. The traffic volume is generally growing. If one thinks at the air traffic, the volume of air traffic continues to grow, more and more machines start and land, the processes become more complex, ...increasingly more technology is needed to automate the human factor. (Expert 2)

This belief is also shared by Expert 1:

> I believe that currently humans represent for me the most serious danger area, for they are the ones who more or less cause accidents. Here could technology a bit intervene, to minimize or eliminate this cause...Fully eliminate is not possible, I believe that no one gives up the 100% control. Not even myself I want this... (Expert 1)

The reserve of this particular expert about the reduction of all human errors by technology represents an interesting illustration of how engineers often feel when working in human-centred technology projects. One the one side, there is a high enthusiasm about the technical possibilities opened in intelligent transportation systems, which is often reinforced by successful development and testing of prototypes and encouraging theoretical results. The reverse of the coin is a growing awareness about difficulty of understanding and grasping the full complexity of human behaviour in system modelling. Some experts manifest an open scepticism about the possibility to understand and control human drivers:

> The human being is the most intelligent system to perform in real-time, and in an intelligent way while machines follow a program and are usually not pro-active" and "Humans are chaotic systems with a great degree of unpredictability". (Expert 4)

The same expert states that human beings are endowed with the flexibility to create new rules and to react to new, previously unknown conditions. On the contrary intelligent systems are programmed to react to a variety of situations imagined by the human being, while not being able to create and invent new rules.

An additional challenge for the design of intelligent systems assisting humans is represented by the high complexity and non-linearity of both human and technical systems. If these two complexities are brought together in a socio-technical system such as the modern traffic, the predictability of system's behaviour is strongly challenged. As expert 3 emphasizes:

> If you look at the traffic modelling or traffic controlling, you see that they are complex systems, random and non-linear. The main cause of this non-linearity is driver behaviour. Traffic rules set frames to drivers, they should behave as such to respect the rules and move between limits of what the traffic should be. Rules are related to some risk in speed, lane change, but there are other behaviours that affect in another may the traffic modelling. I mean the distance between two cars: you have safety margins between them but some drivers do not really follow it or the old women are too afraid to come closer to the car ahead …it is not forbidden to do that but it also affects the traffic (fluidity). (Expert 3)

The experts' acknowledgment of the mixed human and technical problems (failures, breakdowns) in intelligent systems is important for the topic of maintenance and repair insofar it suggests that failing and support (also in the sense of coping with failures) represents a matter of distributed decision and action in which drivers must accomplish themselves some functions of system support. In particular, it is emphasized that humans should remain "actively involved in car operation". Expert 3 stresses that humans should still play the biggest role in driving because "at the present the car alone still cannot follow the traffic rules and interact with other cars alone".

4.2.2. How Does an Advanced Assistance System Fail? And how can its Failing be Recognized and Handled?

Usually the failures of conventional technology can easily be perceived and their causality understood. On the contrary, the failing of intelligent technology is not always immediately visible and manifest. Complex technological systems feature high nonlinearity, fact that makes the comprehension of the impact of a minor failure on the functioning of systems of systems (such as aircrafts) difficult. In addition, some bad parts or processes could be automatically detected by intelligent supervision instances and repaired without involving the end-users. As Expert 7 remarks, there are soft failures, where the performance goes below a specific threshold but the system still functions and the problems are not perceived by users, and system breakdowns, which are fully perceptible by users. Failures can also be intermittent, therefore the real-time monitoring of failures and fault detection are crucial.

The possible failures of driving assistance systems range from poor vehicle stabilization to navigation information that is not correlated with the external context of driving and with the context-based behaviour of the driver. Referring to navigation systems, the interviewed technology designers emphasize that drivers should preserve their awareness and concentration to the road events and properly reason about the information received from the driving information/navigation systems:

> Navigation systems… sometimes give you this direction and this direction is forbidden, you cannot go there. It is maybe because the maps are not updated, therefore the humans should be always aware about this … if the navigation tells you to go to the right you should not trust it completely… You see with your eyes that you can't go to the right. (Expert 4)

Next to such information flops in the databases of navigation systems, a variety of errors and failures may occur at the tactical and operational levels of driving.

> If the system fails, you have a catastrophe. In airplanes, if technology fails they usually move to maneuver mode. In automatic cars they should have such a possibility, for example the car should stop suddenly…alarm or call police/emergency should have procedures when accidents or problems happen. So the idea is also to use technology to call the police, this is also automated. They know the position of your car and can intervene. (Expert 4)

Referring to auto-braking:

> As I gave you this example of auto-braking when the car suddenly comes closer to another car, then it brakes automatically… maybe some drivers really rely on their cars that they really brake. When, something in the system is wrong, they crash together. (Expert 3)

About the parking assistant:

> The sensors have uncertainty and usually normal people are nor really good in information technology and they think that the systems and sen-

sors are 100% accurate, which is not always the case. (Expert 3)

Or: "You get messages that your engines are not working, but they are really working and you don't know what to do!"(Expert 5).

As the quotations above highlight, failures often involve a chain of misunderstandings between humans and technology, ranging from confusions of intentionality (technology usually does not accurately grasp the goal of humans) to the overreliance of humans in technology (drivers are sure that the ADAS will function properly all the time). These tensions between humans and technology are complicated by the reality of modern drivers as laymen who cannot understand anymore "why" things go wrong inside the complex car.

The experts emphasize that particularly the operational failures (related to the driving on the road) should be handled through the possibility to switch to human control or to automatically involve the repair instances. Another important possibility is through the own systems' supervision and control:

> Nowadays, if you don't follow the technology you'll miss everything (talking about the usage of computer to check malfunctioning). Now a screen is connected and you can see which part is damaged. It depends what you want to change or repair. If a tire is kaput the driver can change this, even the sensors, you can change them in principle, but checking them is made by the computer. It is easier not to go there but to look on the computer. For example now by means of the computer you can know how the CPU is working, the state of the hard memory, you should not look inside anymore. (Expert 4)

The opinion that drivers, even if they are monitored by the car systems, should place themselves in the active position of a watchful trust in intelligent technological systems is shared by the majority of the interviewed experts. Drivers should gain trust from the long-term functioning of systems without grave errors, at the same time keeping an open eye on what is happening on the streets and in their cars. Such distributiveness of attention and concentration on different areas is not a simple job and contributes to the worsening of the information overload:

> The driver should not really be outside of this. You can give the role to the system alone, but they (drivers) should be aware that the system can make mistakes… (Expert 4, opinion shared also by experts 2 and 5)

Even if it is desired that drivers should be able to supervise the system:

> This could prove sometimes difficult since there are not always signs such as red lights (in the car) that may warn drivers that something starts to be wrong with the system. (id.)

5. Discussion

5.1. Maintaining and Repairing Intelligent Technology… or Humans?

The current paper has explored the representations of technology designers about advanced driver assistance, failures in intelligent driving, and failure mitigation strategies (who, how, with, what consequences). The expectation has been to identify a dominant view about the instances and possibilities for control and handling of failures that is inscribed in the process of the development of advanced technologies for driver support. To check this expectation, the results of the interviews have been corroborated with the examination of the state-of-the art technology development.

According to the findings, one important function of the advanced driver assistance technology is to ensure that human drivers and driving remain within the desired borders of functionality. This function is distributed on technology and humans. Advanced drivers assistance and particularly driver and driving monitoring systems can be regarded from the perspective of the maintenance and repair topic as forms of "real-time maintenance and repair of drivers". This occurs through the interaction of humans with technology at both latent (technology seaminglessly observes human driving behaviors and states through sensors) and manifest (the artificial agents communicate with humans and vice versa) levels.

The classification below concerns mainly the goals of this type of M&R and is inspired from the maintenance categories of informatics systems including: the corrective maintenance (repairing of errors, modifications of systems to repair errors in design, programming or implementation), adaptive (ensuring the functioning of the system in various changing conditions), perfective (related mainly to the system improvement, new developments), and the continuous support (Alkhatib, 1992). Partially borrowing these terms above, the real-time M&R of drivers can include

A corrective and preventive M&R:

- The automatic recognition of errors, traffic violations, and dangerous driver states, warning (with further possibility of takeover, automatic braking, stop, etc.);
- The maintenance of drivers in a safe state (awake, aware, concentrated) or the enhancement of their context awareness through louder music, automatic adaptation of the car environment (light, temperature).

Perfective maintenance: understood as the extension of human senses to the in-car and out-car perspectives not available before

Restrictive maintenance: the lift out of humans from decisions and actions if the technological monitoring systems automatically classify human states and reactions as risky in a given context.

The intelligent technological assistance understood as "support of human perception, reasoning and actions" (Expert 7) implies that humans remain in the centre of technological actions and assume a variety of responsibilities. In the circle of reciprocal monitoring in Figure 1 the activities of monitoring and fault detection are thus distributed on humans and technology (Figure 1).

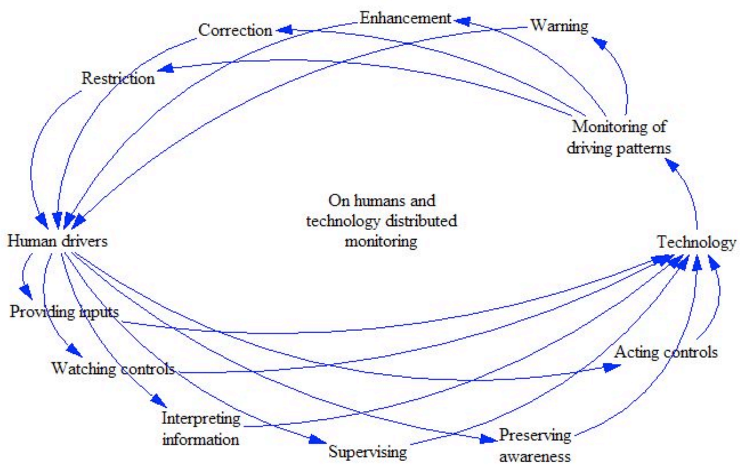

Fig. 1 – The technology script about the reciprocal technology-human monitoring.

The technological monitoring contains various actions such as sensing, data collection, interpretation of information, warning, correction, enhancement and restriction. Some of them require an open interaction with humans, others occur automatically. At their turn drivers give destinations and missions, supervise the car controls, interpret the information in function of the driving context, try to preserve their situational awareness on the road, and (still) drive. A human monitoring of technology functioning is still necessary, even if at a non-expert, superficial level. In driverless cars it is possible that this action range is greatly modified, with the elimination of some actions and decisions and the insistence of the preservation of awareness (doing other things while focusing on the road and technology). There is place for creativity and improvisation in this domain. One such possibility commented by Büscher et al. (2011) refers to participatory sensing. Even the passive car inhabitants of the driverless cars can be endowed with abilities to "sense" their environment and its functioning and to collaboratively contribute to a user-based mutual adjustment of actions and collaborative mobility. The monitoring of a smart system can benefit from the ability of drivers of "reading" the situation and to be creative about this.

It can be concluded that the perspective on maintenance and repair as distributed reciprocal monitoring can represent a good topic for the sociological analysis of the technological co-action in intelligent socio-technical systems (Rammert and Schulz-Schaeffer 2002; Rammert 2007; Weyer 2009; Weyer and Schulz-Schaeffer 2009; Weyer et al. 2015). Particularly "automobilities become more and more hybrid entities in which intelligence and intentionality are distributed between human and non-human in ways that are increasingly isseparable: the governance of cars is no longer in the hands of driver but is assisted by more and more technological add-ons to the point where it becomes akin to a Latourian delegate" (Thrift 2004, 49). Also information infrastructures "are often shaped and intertwined with networks of distributed agency" (Mongili and Pellegrino 2014, xxi). In this context of hybridization answers have to be given about who/what maintains and repairs the hybrid actor (Latour 2006) human-car, or, at a higher level, the "heterogeneous constellation of the intelligent transportation system" (Rammert 2007).

The growing intervention of artificial agents in the daily life and the eventual triumphal march of driving robots will make necessary the empirical investigation of the co-agency of intelligent technology. The expectation is that this will give concrete evidence to its status as a symmetrical actant in the Actor-Network-Theory sense (Latour 2006, 488). It will become more obvious that agency does not represents only the realm of humans, but a connection of actants (ibid, 490) involved in driving, technical failures, and co-monitoring jobs. Recent experiments with an agent-based computer simulation show that human test persons indeed attribute agency to the technical systems" (Fink and Weyer 2014, 47). If driving robots and artificial agents in recommender systems are perceived by users as communicative counterparts and partners in decisions and actions then it makes sense to put questions and do research about the concrete parts that are ascribed to each of them in M&R. Fink and Weyer report about a computer simulation based on an own sociological model called HMSE, allowing them to perform interactive experiments and to observe the issue of distributed agency empirically by identifying the sets of actions performed by humans/technology and ascribing an agency value to them (Fink and Weyer 2014, 60). This approach can stimulate future experiments on the topic of the distribution of roles/agency in the M&R of advanced system-technologies.

5.2. Directions for Future Research

The current empirical study represents the explorative phase of a larger future project that aims at interviewing a larger sample of designers working in various ITS projects. A particular attention will be paid to the consideration of the opinions of female experts, in order to properly consider the impact of gender on the studied topic.

The presented perspective on M&R has the potential of opening new research directions about the problems of monitoring and the chances of advanced technological assistance of humans in general.

A possible problem induced by the technological monitoring of human functionality is the "preventive avoidance of failures" (Weyer 2005) induced by these systems. This could negatively affect the knowledge and the strategic abilities of humans to plan their decisions and reactions in advance. Therefore design strategies to avoid this are required from future research. In relation to intelligent transportations systems it is stressed that the distributiveness of perception, reasoning/decisions and activities on humans and machines in future socio-technical constellations of driving should leave room for human self-initiative; own responsibility; control of personal data; intervention capacity; and the human decision about the real usefulness of applications (Rammert 2007).

The consideration of maintenance and repair as real-time correction, enhancement and repair of human functioning does not only concern the advanced technologies for driving but also other technological systems, which aim at assisting humans in various fields, such as Ambient Assisted Living, Remote Health Care Systems. A comparative analysis of these systems from the maintenance and repair perspective could represent a captivating topic for future research.

Acknowledgements

I would like to offer my special thanks to all my colleagues from The Transportation Informatics Group, University of Klagenfurt for the kind and stimulating support of this research.

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