PERCEPTIONS OF RISK AND CONTROL UNDERSTANDING ACCEPTANCE OF ADVANCED DRIVER ASSISTANCE SYSTEMS

Somya Joshi (ICCS, Greece), Angelos Amditis (ICCS, Greece), Thierry Bellet (INRETS, France), Vanessa Bodard (INRETS, France)

s.joshi@iccs.gr

ABSTRACT: This paper reports on a part of a larger study carried out within the HUMANIST network for excellence, within the remit of a post-doctoral research project. It examines the relationship between driver perceptions of risk and control, and the influence this has on their acceptance of advanced driver assistance systems. The paper describes in depth the unique methodology employed, the experimental design and the analytical framework used. It builds on current knowledge in the area of ADAS acceptance and behavioural adaptation resulting from it.

1 Introduction

With a marked increase in advanced driver assistance systems (ADAS) being designed and deployed for cars, there is a logical emergence of studies that critically examine the influence these have on driver behavior and attitudes towards risk and safety. The research question addressed within this paper asks to what extent the level of perceived criticality or risk on the part of drivers influences their acceptance of advanced assistance. The hypothesis thus tested the relation between increased perception of personal control in a given situation and the influence this has over the acceptance of risk by individuals, as well as on their subsequent acceptance of ADAS. In relation to driving behaviour, by risk perception here we refer to “the subjective experience of risk in potential traffic hazards” [1]. Individual road users experience or anticipate, at any moment in time, a certain amount of loss of control, and they compare this with their target level of risk.

Different research traditions have attempted to explain individual differences in risky driving behaviour and accident involvement. Presently, the technological feasibility of most ADAS is not the main issue for implementation anymore [2]. In fact, the first ADAS applications have already entered the market, such as adaptive cruise controls and collision warning systems. The focus in scientific research on ADAS in the past years has shifted from basic technology research and development towards the complexity and impacts of implementation of ADAS [3]. The present study contributes to this by undertaking an analysis of driver identifications, motivations and preferences with regard to risk-taking behaviour, and subsequently their acceptance of ADAS. The analytical framework of Activity Theory was employed to systematically investigate the complex relationships and tool-mediation that emerge within the present-day augmented environment of intelligent transport. By focusing on the tools (both technological and conceptual) that mediate between our subject group of drivers and our augmented driving environment, this paper attempts to critically examine how diverse driver attitudes towards risk and control can be factored into the design of intelligent in-car systems.

2 Methodology

This paper reports on the findings from a two-year research collaboration within the HUMANIST network[1] The research took place over a period of a year and half, with the support of infrastructure sharing in terms of both equipment and knowledge expertise. An extensive literature review was conducted on the area of risk perception, compensation and ADAS assistance. The development of qualitative interview tools and questionnaires followed this. The uniqueness of this research project lies in its methodology, which combines qualitative, interpretative analysis tools, thereby allowing for a deeper, richer understanding of driver decision-making behaviour and subjective attitudes towards risk and safety.

2.1 Participants

A total of 20 subjects participated in our study, who were selected from a diverse background, cutting across gender, age, driving experience, and license history. With regard to the novice-elderly distribution, the subjects covered ages ranging from 24 to 66 (see fig.1), their experience ranged from 1 to 48 years (see fig. 2). In terms of mileage the subjects varied from below 3000 kms to 100000 kms. Finally, we had a mixture within the group of subjects that had points on their license and those that held a clean license history.

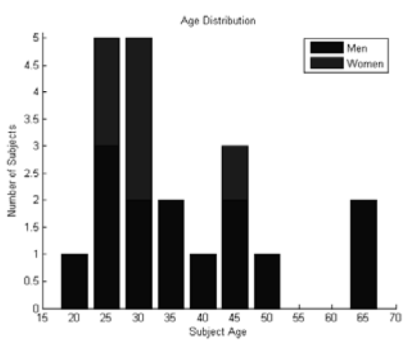

Fig.1. Age/Gender distribution

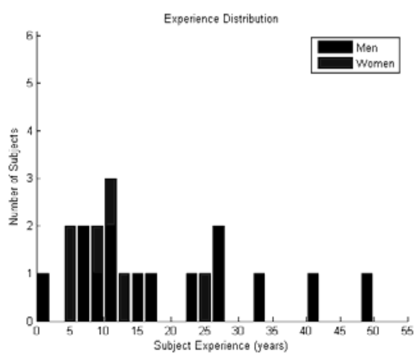

Fig.2. Experience distribution

2.2 Simulator

The simulator we used was a static base one, with a vehicle interface driven by a microcontroller, steering wheel, brake and accelerator with driven torque and effort. The computers used for the simulation were 4 PC:

[1] Between ICCS, Greece and INRETS, France {April 2006 – April 2008}

- 1 PC for dynamic models of the vehicle and the traffic: PC 300Mhz
- 3 PC with high performance graphic card for the visuals (front views and rear views of the road scene): PC 300 Mhz

The front field of view for the Bron simulator was 150° horizontal (on 3 screens) and 40° vertical. The rear-view was embedded in the front view.

2.3 Experimental Design

The simulator part of the experiment was divided into three main stages. These were: Orientation, Non-assistance and Assistance. As the name suggests, during the first stage, we oriented the subjects with the two road environments (i.e. urban/motorway) and allowed them to familiarise themselves with the car and the simulator itself. This was followed by two series (1&2) where the driver experienced a range of critical and non-critical situations, but without any automation or assistance from the intelligent vehicle. Then in series (3&4) they once again experienced a range of critical driving condition, with assistance in the form of automatic breaking, steering control and speed reduction. Warning assistance was given by way of audio (beeps) and visual (flashing diode) signals. Finally the last section of series 4 ended with a near-collision scenario. In addition to variation in terms of degree of criticality, type of assistance, and road environment, we also included dynamic agents within the simulation such as pedestrians crossing the street and motorcyclists. The order of the sections was rotated at random between subjects to counterbalance possible learning effects. At the end of each scenario there was a *freeze* – where the subjects could assess the situation and their response. We experienced no cases of simulator sickness or dropping-out within our sample group.

We designed a questionnaire tailor made for investigating abstract attitudes and subjective perceptions regarding risk and control. The questions varied in response-format from those that required graded answers on a pre-determined scale to those that required elaboration. We asked the subjects to fill out the first set of questions regarding self-assessment before they entered the simulation scenarios, so as to capture their perception prior to engagement with ADAS. Then during the scenarios we asked questions specific to situation awareness and usability during the freezes. After the simulator part, we again asked our subjects to fill in questionnaires and participate in semi-structured subjective interviews, where they had another opportunity to provide rich data on their perceptions of risk and control and their subsequent acceptance or need for ADAS. Apart from Automatic Breaking Systems, none of the subjects were familiar with the advanced assistances systems that we were testing. The interview part of the experiment was divided into two main stages, namely pre-simulation and post-simulation. In the first stage, we interviewed the subjects in depth regarding their self-assessment of personal driving skills as well as identifications with driving styles. We further questioned them regarding their attitudes towards risk-taking and control within the context of automation. In the post-simulator stage, we interviewed the subjects in relation to their perceived performance in the various situations; their awareness of risk, as well as their acceptance of perceived assistance in those same situations. Their interview feedback was recorded both on audio and video. One major limitation of the experiment was its reliance on simulator tests alone and no trials on test-tracks or real roads, especially given the objective of the study being to examine perceptions of ‘risk’. However given the ethical constraints of placing subjects in situations of high criticality, the simulator option emerged as the only feasible one for the moment. As these systems are developed further and introduced in the market, one can carry out field trials, in real traffic conditions.

3 Theoretical framework

Within the broader Human-Computer-Interaction community it has become tacitly accepted knowledge that people cannot articulate what they are doing (a notion sometimes used as a justification for observational studies and sometimes used to avoid talking to users at all). Activity theory within this context has something interesting to tell us about the value of interview data. We have used this framework to critically analyse the complex and rich information we’ve gathered from users about their perceptions and motivations for using ADAS. The fundamental concept of the Activity approach was formulated by Lev Vygotsky [4], who spoke of artefact-mediated and object (motivation)-oriented action. At the apex of this model (see fig.3) lies the mediating tools (instruments) which are situated between the group undertaking the activity (subject) and their desired goals and motivations (object). While the constraints and access points (rules) determine the interactions between the subject group and the stakeholders (community), the hierarchies of power and expertise within an organization (division of labour) mediate between the stakeholder communities and the overarching objectives and outcomes of the activity. It is important to note that an activity system is never static. Tasks are reassigned and re-evaluated, rules are bent and reinterpreted. There is constant movement between the nodes of the activity system. What initially appears as an object may soon be transformed into an outcome, subsequently turned into an instrument, and perhaps later into a rule [5]

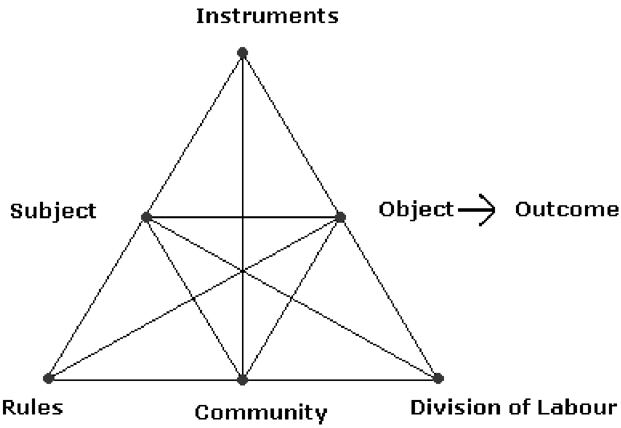

Fig.3. The activity model (Engeström 1987, p.78)

“Tools” mediate the relationship between subject and object, while the relationship between subject and community is mediated by "rules" and the relationship between object and community is mediated by the "division of labour". What is of specific relevance to our study here is the way this model enables us to examine the mediatory role played by ADAS and the influence this has on driver behaviour.

4 Analysis

The environment that we refer to here concerns the physical features of the road (weather, geometry, signs and signals), the driver's own speed and direction, and the paths and speeds of other road users. As subject here we refer to the individual driver, while the instruments in question would be the ADAS and IVIS functions available within the experimental car. Our explicit goal here, or the object, would be to reduce accidents and injury on the road, thereby making the overall environment safer by endowing the subject with more informed decision-making powers. In Fig. 4 below we see this represented within the framework of the activity model.

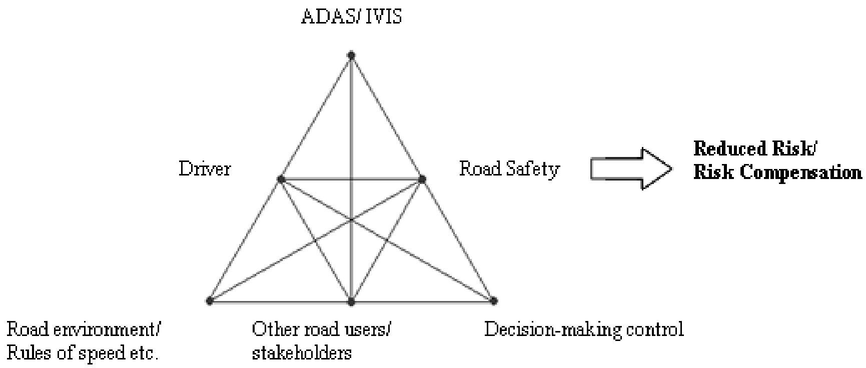

Fig.4. ADAS Activity model

The outcome of the activity however is determined by the interactions between the various nodes. And given the subjective nature of risk it is not surprising that the final outcome of the activity could take form either in line with the desired object of activity or in tangent to it. For instance the perceived level of risk will be relatively low if the driver is confident about having the necessary coping skills, and higher in the case of those who doubt their abilities. This was precisely what was reported by one of our subjects during his self-assessment exercise:

"I consider myself a risk taker, however it is very important for me to be in control. Being in control for me means being aware of what is happening around me, to be at a speed that I can master and in general be in charge of the situation."

Thus our subject was implying that risk taking was acceptable, in so far as the some of the variables were under his control. Taking this a step further, it is logical to argue that individuals differ not only in the accident risk they are willing to accept but also in their ability to *perceive* accident risk and in their decision-making and executive skills in the face of risk. In other words, people differ in both willingness (i.e. acceptance) and ability (skill). Perceptual skill includes the ability to correctly assess one's level of decision-making and vehicle-handling skill. This is important, because it implies that persons with limited decision-making or vehicle-handling skills are at no greater accident risk, provided they realize their limitations and act accordingly.

However as situation awareness varies amongst drivers, so does their subject evaluation of the posed risk. Burger et al. [6], have found that those with a high desire for control exhibited a greater illusion of control (perceived control over chance events). In terms of Risk Compensation, this could mean the allowance of additional risk accepted in line with increased perceptions of control. This is what we referred to earlier as the tangential outcome that the activity could take, where the subject (driver) interacts with his/her environment via certain tools (in this case ADAS) that result in his/her adapted behavior compromising safety. The theory of risk compensation suggests that safety measures which reduce risk to levels below the setting of the “risk thermostat” will be countered by behaviour which reasserts the levels with which people were originally content. If the propensity, or willingness, to take risks is the principal determinant of the accident rate then this rate can only be reduced by measures that reduce the propensity.

The primary functionality of ADAS, as is understood at present, is to facilitate the task performance of drivers by providing real-time advice, instruction and warnings. This type of systems is usually also described by the term “co-driver systems” or “driver support systems”. Driver support systems may operate in advisory, semi-automatic or automatic mode [7], all of which may have different consequences for the driving task, and with that on traffic safety. Although the articulated object or goal of a driver support system is to have a positive effect on traffic safety, unintended effects have been shown on driver behaviour, indicative of negative effects on traffic safety [8]. Firstly, the provision of information potentially leads to a situation where the driver's attention is diverted from traffic. Secondly, taking over (part of) the driving task by a co-driver system may well produce behavioural adaptation. This behavioural adaptation, or compensation as it is called in a wider field, must be taken into account when investigating the conditions for introduction of ADAS [9]. When interviewed post simulation, one of our subjects outlined for us this very feature of compensation.

“When a system adds something that I don’t have, for instance in the case of fog, or night-time if a systems takes control, due to my inability to see well in poor conditions, I can accept that.”

Would this mean that when normally the driver would drive cautiously in such impaired conditions, he would now compensate and thus pay less attention to his immediate environment due to the new options afforded to him via such tools? The critical issue here is one of dependency on a technical artefact that could potentially lead to overlooking crucial variables and affecting the stakeholders in an adverse way. For instance there is now substantial evidence that the effect of risk compensation has been to shift part of the burden of risk from people in vehicles to vulnerable road users outside vehicles, leaving the total number killed in road accidents that could be attributed to seat belt legislation little changed [10].

Real life situations always involve an intertwined and connected web of activities, which can be distinguished according to their objects. Participation in connected activities having very different objects can cause tensions and distortions, as is seen in this case to be risk compensation. For instance the intention or motivation of the ADAS designer would be to enable the driver to better cope with impaired conditions such as fog, low visibility etc. However the motivations underpinning the driver's behaviour might be centered around reducing mental load, and hence once the driver assumes that the ADAS will automatically take over certain functions, he might alter or adjust his level of risk acceptance thereby not achieving the intended object of enhanced safety. Interestingly though perhaps not surprisingly the tolerance for errors in such systems emerged as very low, as was articulated by our subjects:

"As long as the automation was doing something that had not occurred to me before, I'd be glad that it was there. I am more grateful of automation of course in critical conditions. But if it made a mistake even once, I would not use it, as its very important that the car responds in a way that I want it to. A high level of accuracy is imperative."

In addition to the issue of accuracy, two other crucial points are brought forward in the above statement. The first is the co-relation between perceived criticality and the acceptance of assistance, and the second being the co-relation between what action is performed by the ADAS tool and what is perceived as 'want' or motivation behind the subject or driver's action. The acceptance of ADAS was found to vary with driver control [11]; taking the driver out of the loop was considered a problem by many (potential) end-users. An international questionnaire survey carried out by Bekiaris et al, [11], indicated that the driver population was reluctant to release vehicle control, but was willing to accept it in emergency situations. We tested this on our sample group and received responses in support. We start with an elderly driver in our sample who said:

"I am accustomed to being master of my car, so I would be very upset to let go of decisions and have no control. However if I have no chance or options in really critical situations, as in case for example of a big lorry losing control behind me, I'd be happy with automation. Also when I haven't seen a vulnerable road user such as a motorcyclist or pedestrian, I would appreciate some assistance."

Again we see that the subject has accepted a given level of loss of control in situations where the choice is limited and a lot at stake. There is a demarcation made for acceptance in situations where there is clearly and explicitly a value added by the ADAS tool. This sentiment was further reinforced by another member of our sample who said:

"If the situation is under my control, I don't appreciate the car trying to take a decision. It disturbs me. But when I am a prisoner of a situation, i.e. I'm out of options, then its ok by me."

More specifically, regarding the issue of perceived criticality a study found that taking over of control in case of short headway to a lead car was less appreciated than warnings or suggestions of the appropriate action in a test of different types of Collision Avoidance Systems [12]. Although drivers expect a positive safety effect by this type of anti-collision systems and other forms of

ADAS, they have at the same time reservations against it. Handing over control to a device and the automated braking function were evaluated as negative aspects of ADAS systems [13]. In our sample this distinction was also reinforced. For instance drivers clearly indicated which automation functions they regarded as acceptable and which they were strongly against having in their cars. What we found during the course of our experiment is that drivers sought more a 'confirmation' of their assessment of criticality and subsequent decision-making, than an outright decision from the system. A subject from our sample neatly captured this widely held sentiment when he said:

"The efficiency of the assistance depends on how it helps you with a decision in a critical time. So as in this case, I saw the light (diode warning) before I heard the beep, it didn't alarm me, but only confirmed for me that it was a dangerous situation and the right decision to break."

Thus by confirming an already held belief, the function truly assisted the driver in question, rather than further expend his limited attention in a crucial moment. The timing, sequence and intensity of this intrusion was critical in assisting him, and thus not surprisingly was rated high in acceptability value, by him. While more accepting of wider implementation of automation functions, another subject specified the limitations brought by the environment:

"I do not mind if the automation takes control of the car in a motorway, but for sure not in an urban environment, there are just too many variables. If an automation does something unexpected, this can be a limitation, but again this can be solved by training drivers and through education programs."

In a recent study by Comte et al [14], it is demonstrated that drivers are sensitive to the prevailing traffic conditions (environment) when deciding whether to use an advanced assistance system. She investigated driver personality type and the influence this had on their propensity to use such a safety system. Towards this end she employed a questionnaire [2] that allows drivers to rate the acceptability of various driver support systems. The results from this on-road study indicated that those drivers who enjoyed and engaged in speeding, or exceeding the speed limit (i.e. take risks), were less likely to use a system that would inhibit this. This is an incredibly important finding when considering the mechanisms for implementing ADAS: as those drivers who would benefit most would be less likely to use a voluntary system. In order to arrive at a better understanding of what makes drivers more accepting and adopting of ADAS systems, we asked our sample group to qualify their choices in terms of all they experienced during the experiment (automatic breaking, steering control and intelligent speed reduction). One subject responded:

"Relevance of the assistance depends on a situation. Right now as my speed was very slow, I felt in control, even though the situation was very critical. So, I would definitely not want an automated function kicking-in at this point."

Thus our subject qualified three things here. One, her awareness of the situation; two, her subjective evaluation of its criticality, and finally three, her decision to reject automation on grounds of her being in control. These complex and often sub-conscious calculations occur in a dynamic manner within a fraction of a second, thus not surprisingly our sample group had concerns about the ability of an ADAS to respond in similarly complex ways. This brings us to a very important aspect in user acceptance of assistance, namely: Trust. This is linked closely with the previously mentioned factor of accuracy or low tolerance for errors in ADAS enabled vehicles. A member or our sample group brought this to our attention when she said:

"In the case of automation, its very important for me to know that the system will not do something opposite in reaction to what I would have done. It's very important to have this trust. So I would like a test period where the system needs to prove to me that it can make the best choice and I will need to verify this. The system will show me that it can balance pressure and speed in order to do a much better job than me in a surprising (risky) situation."

This emerged as a common thread resonating in the responses of a majority of our sample group. The need for a *match* (i.e. its predictability of action) between the driver's instinctive response in a critical driving situation and the automation response was identified as a major criterion for acceptance.

In figure 5 below we see the shifting nodes of activity with the ADAS context, as represented in the subject responses we have analysed so far. To begin with the subject group can emerge as the designers of ADAS who hold certain assumptions regarding the object of their activity. This could be increased road safety as we looked at before, or simply an acceptance and user market for the systems they create. Also we see that the mediating factor has the potential to shift from the ADAS tool itself to the trust that users can invest in the system, and its predictability of response (in other words the way it *matches* the users intuitive response). An increased reliance on such a system could potentially lead to greater acceptance of risk and this could in turn have unintended effects on the driver and other road user stakeholder group. Finally, even if the driver group decide to relinquish decision-making control onto the system and accept the system, there is no guarantee that a direct co-relation can be drawn between the use of the system and any decline in accidents.

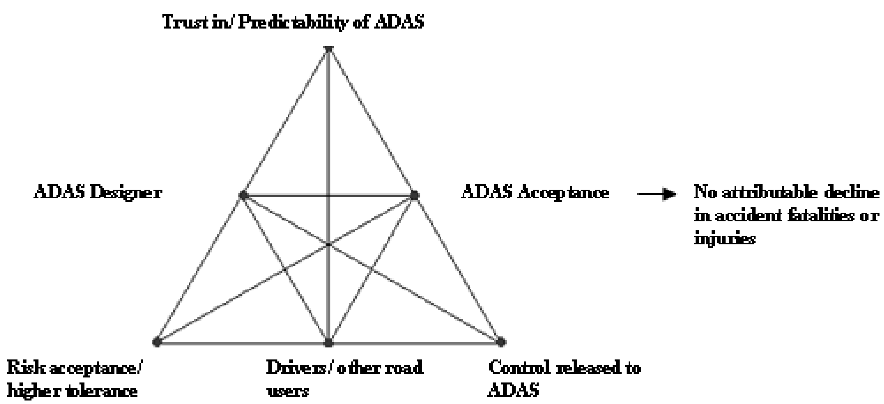

Fig.5. Dynamic nodes of activity

5 Conclusion

To sum, what we have covered here is a rich and complex terrain of driver risk perception, need for control, and subsequent acceptance of advanced assistance systems. Through simulator experiments, in-depth qualitative interviews, as well as situation awareness tests, we have sought to understand how in situations of varying criticality, drivers respond in terms of their acceptance of risk, as well as assistance. The uniqueness of this study lies in the depth of understanding it provides on driver motivations by adopting a qualitative methodology and the analytical tool of the activity framework. Through this lens we have seen how shifting perceptions on risk and control determine the efficacy and acceptance of ADAS systems. We have examined tangents in the activity system that result in outcomes not always matching the desired object, as in this case we saw with risk-compensation. In terms of future directions for this research, we aim at continuing our analysis efforts both in terms of driver diversity in risk-taking, as well as in terms of user acceptance of ADAS. Parallel studies that were conducted using video tools and focussing on sensation-seekers and risk takers, will be integrated with the findings of this project at a wider level.

6 References

[1] Deery, H.A., 1999, Hazard and risk perception among young novice drivers. Journal of Safety Research .30(4), pp 225–236

[2] Van der Laan, Heino, and De Waard's (1997), A simple procedure for the acceptance of assistance of advanced transport telematics. Transportation Research, C 5 (1), 1-1

[3] Heijden, R.E.C.M. van der, Wiethoff, M. (eds, 2000; Eds) Automation of Car driving. Exploring societal impacts and conditions. Delft: DUP. ISBN 90-407-2028-2

[4] Vygotsky, L.S. (1978). Mind in Society. Cambridge, MA: Harvard University Press

[5] Engeström, Y. (1987). Learning by expanding, Helsinki: Orienta-konsultit

[6] Burger, J. M. (1986). Desire for control and the illusion of control: The effects of familiarity and sequence of outcomes. Journal of Research in Personality, 20, pp 66–76

[7] Rosengren, L.G. (1995). Driver assistance and co-operative driving. In: ERTICO (Ed.), Towards an intelligent transport system. Proceedings of the First World Congress on Advanced Transport Telematics and Intelligent Vehicle Highway Systems. London: Artech House, pp 1613-1622

[8] Zwahlen, H.T., Adams, C.C. & DeBald, D.P. (1988). Safety aspects of CRT touch panel controls in automobiles. In: A.G. Gale, M.H. Freeman, C.M. Haslegrave, P. Smith & S.H. Taylor (Eds.). Vision in Vehicles - II. Amsterdam: Elsevier, North-Holland, pp 335-344

[9] Verwey, W.B., Brookhuis, K.A., Janssen, W.H. (1996). Safety effects of in-vehicle information systems. Report TM-96-C002. Soesterberg, the Netherlands: TNO Human Factors Research Institute

[10] Janssen, W.H., The Effect of Seat Belt Legislation on Fatality Rates in a Number of West European Countries, Report Number 1ZF, 1989-13, TNO Institute for Perception, Soesterberg, Netherlands

[11] Bekiaris, E., Petica, S., Brookhuis, K.A. (1997). Driver needs and public acceptance regarding telematic in-vehicle emergency control aids. In: Proceedings of the 4th Word Congress on Intelligent Transport Systems. Brussel: Ertico (on CD)

[12] Nilsson, L. & Alm, H. (1991). Collision Avoidance Systems -Effects of different levels of task allocation on driver behaviour Report DRIVE V1041/GIDS/MAN3. Haren, The Netherlands: University of Groningen, Traffic Research Centre

[13] Hoedemaeker, M. (1996). Needs, driving styles and opinions towards Automated Driving. Report. Delft, The Netherlands, Technical University Delft

[14] Comte, S., Wardman, M., Whelan, G., (2000), Driver' acceptance of automatic speed limiters: implications for policy and implementation. Transport Policy 7, pp 259 - 267