Effects of autonomy, traffic conditions and driver personality traits on attitudes and trust towards in-vehicle agents

Cramer, H.; Evers, V.; Kemper, N.; Wielinga, B.

Published in:
Proceedings: 2008 IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology - workshops: WI-IAT workshops 2008: 9-12 December 2008, University of Technology, Sydney, Australia

Effects of Autonomy, Traffic Conditions and Driver Personality Traits on Attitudes and Trust towards In-Vehicle Agents

Henriette Cramer, Vanessa Evers, Nicander Kemper, Bob Wielinga
Human-Computer Studies lab, University of Amsterdam
{hcramer, evers, wielinga}@science.uva.nl, nicander@gmail.com

Abstract

In-vehicle agents can potentially avert dangerous driving situations by adapting to the driver, context and traffic conditions. However, perceptions of system autonomy, the way agents offer assistance, driving contexts and users' personality traits can all affect acceptance and trust. This paper reports on a survey-based experiment (N=100) that further investigates how these factors affect attitudes. The 2x2, between-subject, video-based design varied driving context (high, low density traffic) and type of agent (providing information, providing instructions). Both type of agent and traffic context affected attitudes towards the agent, with attitudes being most positive towards the instructive agent in a light traffic context. Participants scoring high on locus of control reported a higher intent to follow-up on the agent's instructions. Driving-related anxiety and aggression increased perceived urgency of the video scenario.

1. Introduction

Currently, assistive systems in cars mainly focus on navigation systems, adaptive cruise control and parking assistance. However, not only basic functioning of the cars can be controlled; computers also seek to actively interact with the driver and the environment outside the car [2, 18]. In-vehicle agents can help drivers safely and comfortably reach their destination by helping on tasks such as navigation, assisting drivers in difficult or stressful driving situations and detecting driver states and focusing their attention. Previous work that studied the effects of in-vehicle adaptive information systems included work on adaptive route guidance [23], tourist information [7], adapting to the driver's emotional state [16] and drivers' workload [9]. The results from these studies indicate that adaptation of agent behaviour, information provision and agents' interaction style (e.g. by matching user emotions or personality) indeed influence driver performance and safety, as well as drivers' subjective evaluations. The potential positive impact of these systems can however only be realised if users trust and accept them. Apart from interface design issues, related to e.g. voice interaction and focusing drivers' attention to the road, in-vehicle agent design also needs to overcome challenges inherent to its adaptive nature. These include user control of the system and predictability. Autonomous system decisions might lead to a sense of loss of control, decreased trust and increased driver stress. Agents need to be empathic to the user's experience and also take into account driver's personality traits and behavioural tendencies. The study reported in this paper investigates the effects of system autonomy (informative vs. instructive) and traffic context (heavy vs. light traffic) on attitudes and trust towards in-vehicle agents. Additionally, the effects of personality factors related to locus of control and driving behaviour traits on attitudes towards in-vehicle systems are investigated.

2. Background and hypotheses

Research by Reeves and Nass [19] has shown that people tend to interact with machines as if they were social actors. Especially as system complexity increases and system behaviour is more autonomous and less transparent, people tend to interact with computers in ways mimicking social processes from human-human interaction. Perceived risks of relying on a system and expectations of a system's performance are important factors in trust [13]. Jonnson et al., [12] for example performed a driving simulator experiment with an in-vehicle information system informing the driver of hazards and traffic events. Decreased accuracy of a system reduced both driving performance and trust of the in-vehicle system. Trust however is not dependent on reliability-related features of a system alone. In the context of adaptive cruise control, Rajaonah et al. [18] found that trust in the cooperation with the device determines the quality of interaction between the driver and system, as well as appropriate use. Social aspects, such as system

978-0-7695-3496-1/08 $25.00 © 2008 IEEE
DOI 10.1109/WIIAT.2008.326

etiquette and 'politeness', have also been shown to affect trust and performance, regardless of reliability [17]. The interaction between user and system thus has to convey that a system can be trusted to do well in cooperation with the user. User control and shared initiative, adapted to the individual user, could be key in this interaction.

2.1. User control and in-vehicle systems

Balancing user control and system autonomy is a vital issue in achieving trust. Autonomous system behaviour can lead to a sense of loss of user control. (Perceived) control over adaptivity has been shown to affect user attitudes towards adaptive systems [11] and user trust [3]. Control is also crucial in maintaining combined human-system performance. Desmond et al. [4] found in a simulator study that it is hard for drivers to recover performance when an automatic driving system makes a mistake. Participants who were in full control of driving performed better than participants who used an automatic driving system. Perceived control over a situation or outcome additionally has been shown to be related to the level of stress experienced [14]. This is unsurprising as stress involves perceptions that situational demands exceed a person's abilities and/or resources. An instructive system that appears to make decisions for the driver or instructs the driver to do something can diminish the sense of control, possibly decreasing trust and positive attitudes towards such a system. Instead of taking over the driving task from the driver, a system could for example offer information about stressful conditions ahead. Providing prepatory information can decrease stress reactions and increase perceived control, self-efficacy and performance [10]. Perceived risk might differ between circumstances, as drivers might expect the system's performance (and their own) to vary across situations as well. In time-critical situations where the driver cannot spend much attention to system information or when a driver is stressed, instructions might more preferable to information the driver has to process him or herself. However, stressful, heavy traffic situations might also make the driver feel less secure about depending on a system. Traffic conditions and type of agent (informational, instructive) are therefore expected to interact in their effects on attitudes.

Hypothesis 1: in heavy traffic situations, attitudes will be more positive towards in-vehicle agents that provide information than towards agents that instruct the driver what to do. In light traffic conditions, attitudes will be more positive for instructive agents.

2.2. Personality traits and social context

Goren-Bar et al. [8] have shown that personality traits, especially those related to control, affect attitudes towards adaptivity. In the context of in-vehicle systems, different types of drivers might also benefit from different types of interventions [15]. Users compare their own abilities with those of systems aiming to assist them, to decide whether or not to rely on a system [6]. Drivers who feel less sure about their own abilities might tend to rely on a system more. While intervening when dangerous situations arise could potentially increase road safety, it is important that in-vehicle systems maintain the driver's sense of self-confidence and control over a situation. On the other hand, self-esteem should not be over-inflated for less capable or aggressive drivers; interaction styles should be tailored.

We should also consider the effects of drivers treating in-vehicle agents as social actors. Drivers' personality for examples influences how they anthropomorphise their vehicle [1]. Additionally, Reeves and Nass [19] have shown that social processes in human-to-human interaction also occur in human-system interaction. Nass et al. [16] showed that adapting a car agent's voice to the driver's emotion increases driving performance and drivers' engagement with the car. A design for a stress-adaptive system should consider such individual driver characteristics and the social context of driving. Users' personality and system characteristics need to match. However, the effects of different driving behaviour traits on system acceptance are yet unclear. This study further investigates effects of user characteristics and their attitudes towards in-vehicle systems. We expect that traits specific to driving behaviour also influence attitudes towards systems aimed at driving assistance.

Hypothesis 2: Drivers who are anxious, aggressive or who score low on locus of control will be less positive towards in-vehicle agents.

3. Study

The study took the form of an online survey addressing participants' attitudes towards an in-vehicle agent shown in a short movie clip. Our 2x2 survey-based experiment varied agent autonomy (agent providing information vs. agent instructing the driver) and complexity of the situation (heavy traffic, or light traffic), resulting in four between-subject conditions:

- Heavy traffic, instructive system (H-instr)
- Heavy traffic, informational system (H-inf)
- Low traffic, instructive system (L-instr)
- Low traffic, informational system (L-inf)

Participants were randomly assigned to one of the four conditions. They watched a 15 second movie in which a driver is assisted by an in-vehicle agent and then answered survey items addressing their perceptions of and attitudes towards the agent. We were interested in agents that offer guidance on driving, but do not take over driving. As a case we showed a highway entry situation in which an agent helped the driver match speed with highway traffic and helped assessing when it was safe to merge into traffic. While it might appear unlikely (e.g. for liability reasons), that a system would be developed for this particular scenario, adaptive cruise control and automatic parking systems arguably already make decisions for the users. It is likely such assistance will be offered in more critical situations as well. We chose merging with other traffic as an example of a common, relatively stressful situation in which assistance could be offered. The movies were kept very short on purpose to gauge participants' first reactions. While ideally participants would interact with a (simulated) in-vehicle agent, video-based studies have been found suitable for exploring issues relevant to user attitudes towards systems [8, 24]. Videos were shot on a Dutch highway with a medium-sized car. The driver was a 25 year-old male. The agent was represented by a synthetic male voice providing either information (informational condition) or instructions to the driver (instructive condition) in American-English. Driver and agent gender were matched to counter gender-interaction issues. The videos consisted of four shots:

- Shot of highway & entrance from above.
- Shot of driver from side. Driver was focused on the road. Facial expressions were kept neutral (e.g. not stressed or overly relaxed).
- Shot through the windshield of the entrance lane the car was in and the traffic to the left the driver had to merge into.
- Again a shot of the driver from the side.

The video stopped just before a decision would have to be made whether to follow the agent's advice.

3.1. Manipulations

To manipulate the ***traffic context***, shot 1 differed, showing either a dense or light traffic shot, while the agent voice said "Highway entrance is [busy, not busy], I'll help." depending on the condition.

To vary ***agent autonomy***, the agent either provided instructions (e.g. "Go", "increase speed") or information (e.g. "Six seconds between cars", "traffic speed 90").

Only the amount of traffic shown in the first shot and the vocal information/instructions from the agent differed between conditions; visually shots 2-4 were the same. For the *heavy traffic, instructive* version, the agent's lines were for example: "<shot 1> The highway entrance is busy, I'll help. <shot 2> Wait until I say it's clear. <shot 3> Wait…Wait… <shot 4> Increase speed...Go". For the *light traffic, informational* system, they were: "<shot 1> Highway entrance is not busy, I'll help. <shot 2> I'll provide traffic data. <shot 3> Six seconds between traffic… Traffic speed 90. <shot 4> Six seconds."

3.2. Survey and measures

The survey took about 20 minutes to complete. Demographics, personality and driving traits were addressed first. The video specific to the participant's randomly assigned condition was shown next, after which perceptions of and attitudes towards the agent were gauged. Table 1 lists the final 7-point Likert-type scales used in analysis.

Table 1 Final scales (Cronbach's Alphas, means and ranges) included in analysis

Personality traits: Locus of control α=.702, M=5.3, SD=.98, r:1.0-7.0 3 items, e.g. I like jobs where I can make decisions and be responsible for my own work. *Adapted from [5]*
Personality traits: Driver characteristics *Adapted from [15]* **Thrill seeking** α=.610, M=3.1, SD=1.45, r:1.0-6.5 2 items, e.g. I like to raise my adrenaline levels while driving. **Hazard monitoring** M=4.5, SD=1.54, r:1.0-7.0 I try very hard to look out for hazards even when it's not strictly necessary. **Aggression** M=5.0, SD=1.51, r:2.0- 7.0 I really dislike other drivers who cause me problems. **Anxiety/dislike of driving** M=3.6, SD=1.54, r:1.0-7.0 I find myself worrying about my mistakes when driving.
Perceived competence car agent α=.722 M=3,9 SD=.99, r:1.0-6.67 3 items, e.g. The car agent was very capable at performing its job.
Perceived usefulness car agent α=.774, M=3.7, SD=1.24, r: 1.0-6.33 3 items, e.g. I think that the car agent is useful. *Adapted from [22]*
Attitude towards agent α=.771, M=3.2, SD=1.14, r:1.0-5.67 3 items, e.g. Using the car agent is a good idea. *Adapted from [22]*
Trust α=.806, M=4.23, SD=.63, r:2.4-5.8 16 items: 2 scale items, e.g. I trust the car agent. 14 bipolar semantic differential pairs, e.g. careful – not careful, reliable – unreliable. *Taken from [12]*
Intent to use α=.888, M=2.6, SD=1.4, r:1.0-5.8 4 items, e.g. I would like to have the car agent. *Adapted from [22]*
Intent to follow-up on decision α=.799, M=3.6, SD=1.57, r:1.0-7.0 2 items, e.g. I would follow the car agent's directions

4. Results and discussion

100 participants were included in the study. The majority were Dutch (70.7%), with a mean age of 33. Twenty-six participants were female. All participants had a driver's license (M=15 yr). No differences were found between conditions on age, education level, locus of control and driving behaviour traits.

4.1. Manipulation checks

Our manipulations were successful. Scores on the scale 'The amount of traffic in the video can best be described as [very light traffic - very heavy traffic]' were significantly higher in the heavy traffic condition than in the light traffic condition (U=902.500 p(1-tailed)=.0075, M(H)=5.13, Mdn(H)=5.0, M(L)=4.57, Mdn(L)=5.0). Scores for participants in the instructive condition on 'The car agent makes important decisions for the driver' were significantly higher than those in the informational condition (U=720.500, p(1-tailed)<.001, Mdn(Instr)=4.0, Mdn(Info)=3.0).

4.2. Effects traffic and agent type

Interaction effects Two-way, independent ANOVAs with agent type and amount of traffic as factors were used to check for interaction effects between type of agent and traffic conditions (with Adjusted Rank Transform (RT) for non-normal distributed constructs, as described in [20]). Interaction effects (Fig. 1) were found for perceived usefulness (F(1,95)=4.023, p=.048), attitude towards the agent (F(1,95)=6.520, p=.012), trust (F(1,85)=4.100, p=.046) and intent to use (RT F(1,95)=7.303, p=.008). No interaction effect was found for perceived agent competence. Simple effects analysis showed that in heavy traffic conditions, scores for perceived usefulness, attitude, trust and intent to use did not significantly differ between the instructive and informational agent. However, in light traffic scores for the instructive agent on perceived usefulness, attitude, trust and intent to use were all significantly higher (p<.05) than for the informational agent (Table 2). Participants preferred the instructive agent, but this preference only holds in light traffic conditions.

Effects agent type A significant main effect of type of agent was found for perceived competence. The instructive agent was perceived as more competent (M=4.0) than the informational agent (M=3.7) (H(1,95)=11.753, p=.001, Kruskal-Wallis as non-parametric alternative). A main effect of type of agent was also found for perceived usefulness of the agent (F(1,95)=11.796, p=.001); which was higher in the instructive (M=4.0) than in the informational condition (M=3.2). This effect on perceived usefulness is moderated by the interaction effect discussed above; only in light traffic the instructive agent was indeed rated as more useful. No main effects were found for intent to use, trust and attitude.

Effects traffic A main effect of traffic conditions was found for participants' intent to follow-up on the system's instructions. Participants were less willing to let the driver follow up on agent decisions in heavy traffic (M=3.3) than in light traffic (M=3.9), F(1,54)=1.693, p(1-tailed)<.001. No significant main effects were found for traffic on perceived usefulness, perceived competence, attitude, trust and intent to use.

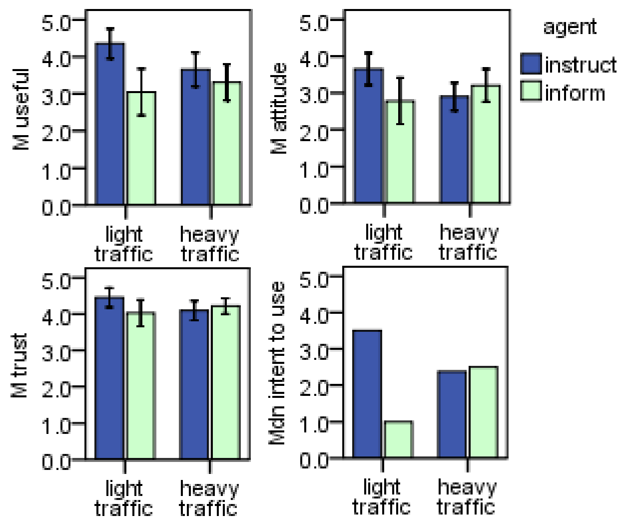

Fig. 1 Effects traffic context, autonomy for usefulness, attitude, trust and intent to use. 95% CI.

Table 2 Means/Medians (selected constructs, 1-7 scale)

		Useful		Attitude		Trust		Intent to use	
Traffic	**Agent**	M	SD	M	SD	M	SD	Mdn	SD
Heavy	Instr	3.6	1.1	2.9	.94	4.1	.60	2.4	1.2
	Inf	3.3	1.3	3.2	1.2	4.2	.51	2.5	1.4
Light	Instr	4.4	1.1	3.7	1.2	4.5	.69	3.5	1.6
	Inf	3.0	1.1	2.8	1.1	4.0	.65	1.0	.98

Discussion effects traffic and agent type The results above indicate that perceptions and attitudes towards the type of agent are affected differently in different traffic contexts. Only in light traffic did participants prefer the instructive agent over the informational agent. Even though it might appear likely that in heavy traffic and time-critical situations drivers might prefer more instructive agents providing 'ready-to-use' instructions, instead of information that still needs to be processed, this was not the case in this study. It is possible the instructions of the instructive agent were more readily understood, or seen as more relevant, than the information provided in the informational condition. This might be an explanation why the instructive agent was seen as more competent; the way an agent provides information can be just as important in users' perceptions of agent as the amount of control they have over an agent. The relatively low scores (Table 2) overall for both types of agents could indicate participants would rather not rely on a system. Clear instructions might be preferred to information that needs to be processed, but in more critical situations and in the specific merging scenario used here, participants appear more inclined to rely on themselves. Agents that help drivers' performance by e.g. providing prepatory information when approaching stressful situations might be appreciated more than agents interfering with driving decisions 'on the spot'. This does not mean that e.g. just-in-time information that might help avoid accidents is not useful, but clear warnings might be better than instructions.

4.3. Effects of personality and driving traits

For all personality and driving trait related constructs, participants were divided in a high and low scoring group based on the mean for parametric and median for non-parametric distributions. These groups were then compared on the main constructs.

Locus of control Locus of control affected compliance. Participants who scored high on locus of control tended to report the driver should follow the agent's instructions more (Mdn=4.0) than those scoring low on locus of control (Mdn=3.0) (U=255.500, p(1-tailed)=0.048). No other effects of locus of control were found.

Driving traits Driving traits were not found to affect participant attitudes towards the agent. However, there were differences on perceptions of the traffic context in the video. High-anxiety participants thought the situation in the video was more time-critical (U=576.500, p(2-tailed) =.022, Mdn=6.0), than those participants scoring low in dislike of driving/anxiety (Mdn=5.0). Participants who scored high on aggression, also thought the situation was more time-critical (U=475.000, p(2-tailed)=.004, Mdn(H)=5.0, Mdn(L)=4.0). Anxiety and aggressive driving tendencies affect the perceptions of traffic conditions.

Discussion effects of personality traits The findings of [8] that persons who score high on locus of control appear more willing to relinquish control to an adaptive system was confirmed here. The findings concerning driving traits show the importance of taking such traits into account in studies involving car agents, as they influence how participants view certain situations. We found no direct effects of driving related traits in this study on agent acceptance, future research on in-vehicle agents should explore which individual aspects of driving styles are important and how they can be accommodated. Including more extensive driving trait scales [15] would be helpful.

5. Conclusion and future work

This study shows that perceptions of, trust in and attitudes towards in-vehicle agents are affected by both traffic context and autonomy of an agent in terms of the level of information or instructions offered. Significant interaction effects were found between traffic context and the type of agent for perceived usefulness, attitude towards the agent, trust and intent to use. Only in the context of light traffic participants preferred the instructive agent, in the heavy traffic attitudes were at a similar, slightly negative level, for both types of agents. An in-vehicle agent thus might not be accepted in all contexts. The study's results showed that personality traits can affect attitudes towards agents, with locus of control affecting the willingness to follow an agent's instructions, supporting the findings of [8]. We could not confirm that traits specific to driving affect attitudes towards in-vehicle agents. These traits did however affect perceptions of the interaction scenario. Future studies into trust and acceptance of adaptive systems should take into account general personality traits such as locus of control, as well as traits specific to the application context.

Further research should overcome the limitations of this study as an exploratory video-based survey, showing only one short interaction with non-ideal agents. The findings of this study can be used to inform to further studies involving driving simulators or actual situations. Beyond in-vehicle agents, issues surrounding system autonomy, context and personality traits should be further explored for other context-aware and user-adaptive systems as well.

Balancing user control and system autonomy is a vital issue in interaction with in-vehicle agents. The agent in our instructive condition was perceived as making decisions for the user, but it would not take over driving from the user; the driver still got to decide whether the system instructions were valid. At this time, we would argue for the development of in-vehicle systems that adapt to driver personality and are unobtrusive mixed-initiative agents that do not attempt to take over driving. Levels of autonomy and interaction styles however also have to be dynamically adapted to current driving contexts, road and driver states.

6. Acknowledgements

We thank our participants. This study is funded by the ICIS project, BSIK03024, by the Dutch Ministry of Economical Affairs.

7. References

[1] J. Benfield., W. Szlemko and P. Bell, "Driver personality and anthropomorphic attributions of vehicle personality relate to reported aggressive driving tendencies", *Personality and Individual Differences*, 42(2), 2007, pp. *247-258.*

[2] D. Boehm-Davis, A. Marcus, P.A. Green, H. Hada and D. Wheatley, "The next revolution: vehicle user-interfaces and the global rider/driver experience", *CHI'03*, Ft. Lauderdale, USA, 2003, pp. 708-709.

[3] C. Castelfranchi and R. Falcone, "Trust and Control: A Dialectic Link", *Applied AI*, 14 (8), 2000, pp. 799-823.

[4] P. Desmond, P.A. Hancock and J. Monette. "Fatigue and automation-induced impairments in simulated driving performance", *Transportation Research Record 1628*, 1998, 8-14.

[5] P. Duttweiler, "The internal control index: a newly developed measure of locus of control", Educational and *Psychological Measurement*, 1984, pp.61-74.

[6] M. Dzindolet, S. Peterson, R. Pomranky, L. Pierce and H.P. Beck, "The Role of Trust in Automation Reliance", *Int. J. of Human-Computer Studies*, 58 (6), 2003, pp. 697-718.

[7] C. Gena and I. Torre, "The importance of adaptivity to provide onboard services: A preliminary evaluation of an adaptive tourist information service onboard vehicles", *Applied AI,* 18, 2004, pp. 549-580.

[8] D. Goren-Bar, I. Graziola, F. Pianesi and M. Zancanaro, "The influence of personality factors on visitor attitudes towards adaptivity dimensions for mobile museum guides", *User Modeling and User-Adapted Interaction*, 16(1), 2006, pp. 31-62.

[9] M. Hoedemaeker and M. Neerincx "Attuning In-Car User Interfaces to the Momentary Cognitive Load", *HCII'07*, Beijing, China, 2007, pp. 286-293.

[10] C. Inzana, J. Driskell, E. Salas and J. Johnston, "Effects of Preparatory Information on Enhancing Performance Under Stress", *Applied Psychology*, 81(4), 1996, pp. 429-435.

[11] A. Jameson and E. Schwarzkopf, "Pros and Cons of Controllability: An Empirical Study", *AH'02,* Malaga, Spain, 2002, pp. 193-202.

[12] I-M. Jonnson, H. Harris and C. Nass, "How accurate must in-car information systems be? Consequences of accurate and inaccurate information in cars", *CHI'08*, Florence, Italy, 2008, pp. 1665-1674.

[13] A. Jøsang and S. Lo Presti, "Analysing the Relationship between Risk and Trust", *Int. Conf. on Trust Management*, 2004.

[14] L. Lu, H.L. Wu and C.L. Cooper, "Perceived work stress and locus of control: a combined quantitative and qualitative approach", *Research & Practice in Human Resources Management*, 6, 1999, pp.51-64.

[15] G. Matthews, P.A. Desmond, L. Joyner, B. Carcary and K. Gilliland, "Validation of the driver stress inventory and driver coping questionnaire", *Int. Conf. on Traffic and Transport Psychology*, Valencia, Spain, 1996.

[16] C. Nass, I. Jonsson, H. Harris, B. Reaves, J. Endo. S. Brave and L. Takayama, "Improving automotive safety by pairing driver emotion and car voice emotion", *CHI'05*, Portland, USA, 2005, pp. 1973-1976.

[17] R. Parasuraman and C. Miller, "Trust and etiquette in high-criticality automated systems", *Commun. ACM,* 47(4), 2004, pp. 51–55

[18] B. Rajaonah, F. Anceaux and F. Vienne, "Trust and the Use of Adaptive Cruise Control: a Study of a Cut-In Situation", *Cogn, Techn & Work* 8 (2), 2006, 146-155.

[19] B. Reeves and C. Nass, "*The Media Equation: How People Treat Computers, Television and New Media Like Real People and Places*", CSLI, New York, 1998.

[20] S.S. Sawilowsky, "Nonparametric Tests of Interaction in Experimental Design", *Review of Educational Research*, 60(1), 1990, pp. 91-126

[21] L. Takayama and C. Nass, "Driver safety and information from afar: An experimental driving simulator study of wireless vs. in-car information services"*, Int. J. of Human Computer Studies*, 66 (3), 2008, pp. 173-184.

[22] V. Venkatesh, M. Morris, G. Davis and F. Davis, "User acceptance of information technology: Toward a unified view", *MIS Quarterly*, 27(3), 2003, pp. 425-478.

[23] P. Vries, C. Midden and D. Bouwhuis, "The effects of errors on system trust, self-confidence, and the allocation of control in route planning." *Int. J. of Human Computer Studies*, 58, 2005, pp. 719-735.

[24] Woods, S., Walters, M.L., Koay, K.L. and Dautenhahn, K., Methodological issues in HRI: A comparison of live and video-based methods in robot to human approach direction trials. *ROMAN 2006*, Hatfield, UK, 2006, pp. 51-58.