ACCEPTANCE OF DRIVER SUPPORT SYSTEMS

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ABSTRACT: Driver support systems aimed at improving traffic safety have undergone considerable development of late, but these technological systems obviously have to be used by drivers if they are to be successful in reducing fatalities and trauma. For this, driver acceptance of the system is vital. The recognized importance of acceptance notwithstanding, there is no common definition of what it is in terms of driver support systems. This paper examines the definition of acceptance of driver support systems. It also makes reference to previous experiences from the information technology area and to a pilot test, using data from a field trial with a driver support system, of whether the Unified Theory of Acceptance and Use of Technology (UTAUT) may also be used as a framework for understanding the acceptance of driver support systems is carried out. The results support to some extent the use of UTAUT as a model for acceptance of driver support systems.

1 INTRODUCTION

Recent years have seen substantial development of different driver support systems aimed at improving traffic safety. For instance, Intelligent Speed Adaptation, (ISA), Forward Collision Warning (FCW), Automotive Collision Avoidance System (ACAS), Fatigue Monitoring, Road-Departure Crash Warning System (RDCW) and Lane Departure Warning (LDW) have been developed and tested (see e.g. [1], [2], [3], [4], [5] and [6]). If these technologies are to be successful in reducing fatalities and trauma, they have to be used by drivers. For this, driver acceptance of the system is vital. This is recognised by many, e.g. Najm et al [4], who state that "driver acceptance is the precondition that will permit new automotive technologies to achieve their forecasted benefit levels", and van der Laan et al. [7] see acceptance as the link to use, thereby materializing the potential safety effects, and conclude that "it is unproductive to invest effort in designing and building an intelligent co-driver if the system is never switched on, or even disabled".

It is the driver who makes the decision to use or not use a system. Since acceptance is individual, it can only be based on an individual's personal attitudes, expectations, experiences and subjective evaluation of the system and the effects of using it [8]. The effects of the system (e.g. reduction in accident risk) can only influence acceptance if they are known, understood and believed in by the driver. A misunderstanding of the system will influence acceptance as much as a correct conception. To achieve the acceptance and use of new systems, personal importance to the users has to be valued more highly than degree of innovation (see e.g. [9]). However, the technology push is high and policies and political goals are often confused with the driver's personal goals. Societal goals and individuals goals do not necessarily coincide. For example, the policy goal behind ISA could be to increase traffic safety or to increase speed limit compliance. These goals might not be relevant to some drivers e.g. due to their feeling that safety measures are redundant because of their own personal driving skills [10], or that speeding is not seen as a “real crime” [11]. Nevertheless, they might find that the system helps them to avoid speeding tickets or that they have an interest in innovative systems.

Despite the recognized importance of acceptance, there is no prevailing definition of what it is or how to measure it in terms of driver support systems. The many different ways of assessing acceptance may cause confusion and lead to incorrect conclusions or interpretations. In a literature review, reported in [12], 9 different approaches to measure acceptance were found. Most researchers measure acceptance without defining it, thereby defining it implicitly by the measurements whey use. This makes the validation of the measurements impossible.

The present situation is troublesome. If acceptance is not defined, then we cannot be sure that the tool we use to measure it will give valid results. And without knowing how acceptance is defined it is impossible to understand how drivers’ experiences influence it. The inconstancy of acceptance definitions (implicitly defined or not), and of measurements and thereby the diversity of results – even though collected in the same experiment (see e.g. [13] and [14]) present a breeding ground for misinterpretations and misuse of the results. What is more, it makes comparisons between systems and settings almost impossible.

2 DEFINITION OF ACCEPTANCE

2.1 Present definitions of driver acceptance

Definitions of acceptance were found through a literature review in the databases Transport and Elin (Lund University’s Electronic Library Information Navigator), supplemented with relevant papers, reports, presentations etc. (for more details about the literature review see [12].

The definitions were classified into five categories. The first category uses the word “accept” to define acceptance. The second category is concerned with the needs and requirements of users (and other stakeholders). This may be interpreted as the usefulness of the system. The third category of definition sees acceptance as the sum of all attitudes, implying that other, for example, more emotionally formed attitudes are added to the more “rational” evaluation of the usefulness of the system (as in category 2). The fourth category focuses on the will to use the system. This definition of acceptance aims for a behavioural change and may be seen as being based on the earlier categories, in that the will to use a system is based on drivers’ assessment of the usefulness of the system (as in category 2) as well as all other attitudes to the system and its effects (as in category 3). This fourth category stresses the will to act as a consequence. The fifth category of acceptance emphasizes the actual use of the system, which presumably is influenced by the will to use it (as in category 4).

Viewing the categories like this, they may to some extent be seen as a progression from assessing the usefulness of a system towards the actual use of that system, the later categories including the earlier ones. This progression perspective, however, cannot include category 1, which uses the word "accept" to define acceptance, but does not provide any information about what is implied by acceptance or accept.

There are also different types of acceptances described in the literature. Authors have made distinctions between attitudinal and behavioural acceptance [15], [16], between social and practical acceptance [17] and between different levels of problem awareness of the individual [18]. There is also discussion about 'conditional' [19] and 'contextual' [20] acceptance in the literature. Goldenbeld [21] makes a distinction between acceptance and support, where acceptance is the willingness to be subjected to something (e.g. pay taxes) while support is the liking for doing so and some stress the importance of making a distinction between acceptability and acceptance (e.g. [22]).

2.2 Proposal for a new definition of acceptance

The use of the system is vital in striving to improve traffic safety by deploying driver support systems. It is the use of the system that will materialise its potential and hopefully produce benefits for the driver and the society. Neither attitudinal acceptance [16] nor support [21] requires any impact on the actual use of a system. Hence, the main aim and focus should be on behavioural acceptance [16], the utilization level as described by Kollmann [15] or the acceptance definition category 5 – actual use, which emphasizes the use of the system. From this perspective, the second and third categories of acceptance definitions (usefulness and all attitudes), attitudinal acceptance [16] and the attitude level described by Kollmann [15] influence the will to use and the actual usage, but are not to be seen as acceptance.

The proposed acceptance definition, postulates that acceptance is "the degree to which an individual intends to use a system and, when available, incorporates the system in his/her driving". This definition establishes the relationship between acceptance and use, implied by many researchers. Further, it stresses the importance of user centred view and the importance of manifesting the intention to use the system in actual behaviour. By this definition a driver does not have to like to use the system to demonstrate acceptance. It is enough that he/she 'tolerates' the use. The definition also implies that there are different degrees of acceptance, that it is not limited to acceptance/no acceptance but to be of a more continuous nature, and could of course also be zero.

3 A PILOT TEST OF THE UTAUT MODEL IN THE CONTEXT OF DRIVER SUPPORT SYSTEMS

3.1 The Unified Theory of Acceptance and Use of Technology

Following the rapid development of new technologies and software in computer science, interest in the acceptance and use of these technologies has increased significantly. A number of different models are used in the information technology area, which today includes one of the most comprehensive research bodies on the acceptance and use of new technology. In 2003, Venkatesh et al. [23] integrated eight of the most significant models of individual acceptance into one comprehensive model - The Unified Theory of Acceptance and Use of Technology (UTAUT), see Figure 1.

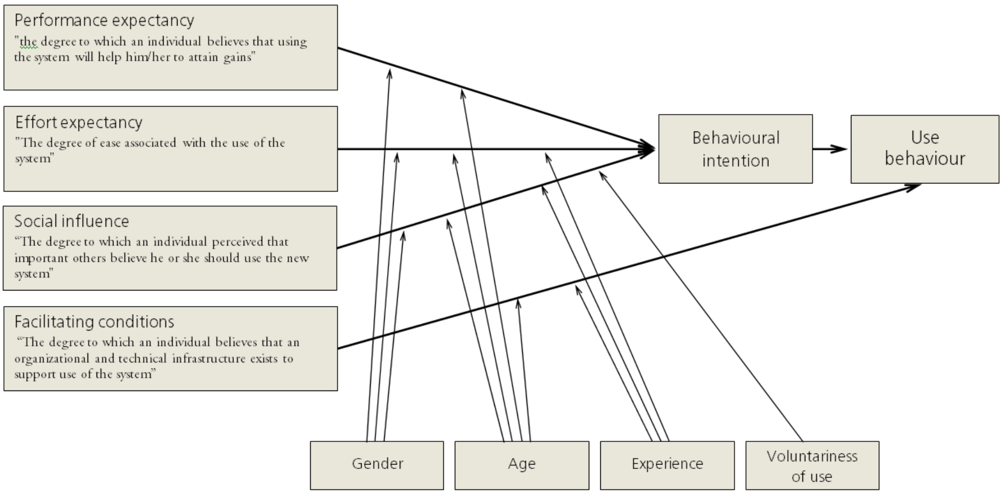

Figure 1: The Unified Theory of Acceptance and Use of Technology (UTAUT) and definitions of the constructs [23]

The model is based on an extensive literature review and empirical comparison of the Theory of Reasoned Action, the Technology Acceptance Model, the Theory of Planned Behaviour, a model combining the Technology Acceptance Model and the Theory of Planned Behaviour, the Model of PC Utilization, the Motivational Model, the Social Cognitive Theory and the Innovation Diffusion Theory, including their extensions [23]. The key element in all these models is the behaviour, i.e., use of the new technology. In a validation of the acceptance and use of computer software by workers in the USA, the UTAUT model outperformed the eight individual models, accounting for 70 percent of the variance (adjusted R2) in use [23].

The model postulates two direct determinants of use: ‘intention to use’ and ‘facilitating conditions’. ‘Intention to use’ is in turn influenced by ‘performance expectancy’, ‘effort expectancy’ and ‘social influence’. Gender, age, experience and voluntariness of use act as moderators, see Figure 1.

The UTAUT model has also been utilized in other areas such as adoption of mobile services among consumers [24] and in the health sector (e.g. [25], [26], [27] and [28]). The studies largely support the appropriateness of the UTAUT model in these areas. However, the social influence was not found to be as strong a predictor as suggested by the model when investigating information/communication technologies and decision support in the health sector [26] and [27]. Extensions/modifications of the model were recommended both in the adoption of mobile services area and within the health sector [24] and [25].

3.2 Using the UTAUT for a driver support system – a pilot test

To investigate the UTAUT model in the context of driver support systems, a pilot test was carried out in 2008. Data for this pilot test was collected in 2006 and 2007 during field trials to evaluate a prototype driver support system (SASPENCE). The original model was applied as far as possible. However, the experimental design of the field trials could not be modified for the evaluation of UTAUT. Nevertheless, additional questions to the already planned questionnaires allowed data collection for examination of the inter-relationships of 'performance expectancy', 'effort expectancy', 'social influence' and 'intention to use', including gender and age as moderators. A summary of the trial is given below, more details about the trial are reported in [6] and [12].

3.2.1 Method

The SASPENCE system is a driver support system which assists the driver to keep a safe speed (according to road and traffic conditions) and a safe distance to the vehicle ahead. The "Safe Speed and Safe Distance" function informs/warns the driver when a) the car is too close to the vehicle in front, b) a collision is likely due to a positive relative speed, c) the speed is too high considering the road layout and d) the car is exceeding the speed limit. The driver receives information and feedback from the system by means of an external speedometer display located on the instrument panel, haptic feedback in the accelerator pedal or in the seat belt and an auditory message when a too short headway could lead to imminent danger.

Two different test routes were used to evaluate the system, one in Turin, Italy, and one in Valladolid, Spain. Both routes were approximately 50 km long and contained both urban and rural road stretches and a motorway section. The test drivers drove the test route twice, once with the system on and once with the system off, thus serving as their own controls. The order of driving was altered to minimize bias due to learning effects.

At each site, 20 randomly selected inhabitants, balanced according to age groups (18-24, 25-44, 45-64 and 65-69) and gender, participated in the trial. Unfortunately, the data for one test driver was lost due to system failure in Italy, and one of the test drives in Spain was cancelled for safety reasons.

Before the drivers used the SASPENCE system, they were given a brief explanation of the system. The questions regarding the UTAUT assessment were given to the drivers as part of the questionnaire after the second drive.

The items for assessing 'behavioural intention', 'performance expectancy', 'effort expectancy' and 'social influence' were adopted from Venkatesh et al. [23]. Some of the items had however to be adapted to fit the context of driver assistance systems, see Table 1. Each item was measured using a seven-point scale, ranging from "strongly disagree" (1) to "strongly agree" (7) (identical to [23]).

Table 1: The original UTAUT items and the modified items used in this study to assess acceptance of driver support systems.

	Original items [23]	Modified items
Behavioural intention to use the system (BI):		
		Imagine that the system was on the market and you could get the system in you own car.
BI1	I intend to use the system in the next <n> months	I *would* intend to use the system in the next 6 months
BI2	I predict I would use the system in the next <n> months	I *would* predict I would use the system in the next 6 months
BI3	I plan to use the system in the next <n> months	I *would* plan to use the system in the next 6 months
Performance expectancy (PE):		
PE1	I would find the system useful in my job	I would find the system useful in my *driving*
PE2	Using the system enables me to accomplish tasks more quickly	Using the system enables me to *react to the situation more quickly*
PE3	Using the system increases my productivity	Using the system increases my *driving performance*
PE4	If I use the system, I will increase my chances of getting a raise	If I use the system, I will *decrease my risk of being involved in an accident*
Effort expectancy (EE):		
EE1	My interaction with the system would be clear and understandable	My interaction with the system would be clear and understandable
EE2	It would be easy for me to become skilful at using the system	It would be easy for me to become skilful at using the system
EE3	I would find the system easy to use	I would find the system easy to use
EE4	Learning to operate the system is easy for me	Learning to operate the system is easy for me
Social influence (SI):		
		Imagine that the system was on the market and you could get the system in you own car.
SI1	People who influence my behaviour would think that I should use the system	People who influence my behaviour would think that I should use the system
SI2	People who are important to me would think that I should use the system	People who are important to me would think that I should use the system
SI3	The senior management of this business has been helpful in the use of the system	The *authority would be* helpful in the use of the system
SI4	In general, the organization has supported the use of the system	In general, the *authority would* support the use of the system

3.2.2 Results

Factor analysis confirmed on the whole the similarity of the items within the four constructs. However, items PE3 and PE4 did not show high loadings on performance expectancy. Item PE3 showed more resemblance to social influence while item PE4 did not show any clear resemblance to any of the four constructs. One explanation for this might be that the transformation of items

PE3 and PE4 from the context of IT to driver support system brought about a different meaning. Together with the low loadings on 'performance expectancy', it was decided to exclude both these items from further analysis, which increased the content validity. The remaining items were represented by four summated scale variables (averages of item scores).

The internal consistency reliabilities of the summated scale variables were tested with Cronbach's Alpha coefficient (α). All constructs demonstrated an internal consistency higher than 0.70, (BI: 0.862, PE (PE3 and PE4 excluded): 0.728, EE: 0.764, SI: 0.721).

The relationships between the independent constructs (PE, EE, SI) and intention to use the SASPENCE system (BI) were examined by applying linear regression analysis. First, the unadjusted effects, i.e. crude effects (meaning that there was only one independent variable in the model) and then the adjusted effects of variables (by simultaneously entering other independent variables into the model) were analysed. The results obtained by the analyses are shown in Table 2.

Table 2: Effects of independent variables on the dependent variable 'behavioural intention' (BI), based on linear regression models

Independent variable in the model	Coefficient ($\beta_{standardized}$)	p-value	$R^2_{adjusted}$	Model
Performance expectancy				
PE	0.41**	0.011	0.15	BI = a + β*PE
PE, EE	0.38**	0.025	0.13	BI = a + β *PE + c*EE
PE, SI	0.37**	0.015	0.22	BI = a + β *PE + c*SI
PE, EE, SI	0.36**	0.027	0.20	BI = a + β *PE + c*EE + d*SI
Effort expectancy				
EE	0.22	0.186	0.02	BI = a + β *EE
EE, PE	0.10	0.522	0.13	BI = a + β *EE + c*PE
EE, SI	0.16	0.306	0.10	BI = a + β *EE + c*SI
EE, PE, SI	0.06	0.704	0.20	BI = a + β *EE + c*PE + d*SI
Social influence				
SI	0.35**	0.030	0.10	BI = a + β *SI
SI, PE	0.31**	0.042	0.22	BI = a + β *SI + c*PE
SI, EE	0.32**	0.048	0.10	BI = a + β *SI + c*EE
SI, PE, EE	0.30*	0.053	0.20	BI = a + β *SI + c*PE + d*EE

PE: performance expectancy, EE: effort expectancy, SI: social influence ** $p<0.05$; * $p<0.10$

'Performance expectancy', i.e., the expected benefits gained by using the system, had a significant positive effect on intention to use the system. It had a significant crude effect, and only small changes in the coefficient of determination were observed when other independent variables (EE and SI) were added to the model.

The same pattern was observed for 'social influence', which also demonstrated a significant positive crude effect on intention to use the system and only small changes in the coefficient of determination when the other independent variables (PE and EE) were added to the model.

However, ‘effort expectancy’ showed no significant direct relation to intention to use the system. No significant effects could be found together with ‘performance expectancy’ and ‘social influence’. Further, when including the effort expectancy in the model, the adjusted explanatory power decreased.

The explanatory power of the UTAUT model for intention to use the SASPENCE system (BI) was 20 % when all independent variables were included (PE, EE and SI). ‘Performance expectancy’ (PE) and ‘social influence’ (SI) had a significant impact on ‘behavioural intention’ (BI). The standardised beta coefficient revealed that the impact of ‘performance expectancy’ was slightly more significant than that of ‘social influence’. In this data material the ‘effort expectancy’ (EE) did not show any correlations to ‘behavioural intention’.

The inclusion of the moderators ‘gender’ and ‘age’ did not affect the results, regardless of whether ‘effort expectancy’ was included in the analysis or not.

4 DISCUSSION

Good academic practice emphasises the importance of being clear and distinct to minimize ambiguity and to facilitate comprehension and revision of the scientific work presented. However, in ITS research the definition of ‘acceptance’ is usually taken for granted and most researchers assess acceptance without defining it. This is one of the fundamental problems in acceptance research today. The different ways of measuring acceptance makes comparisons between different studies and different systems difficult.

The proposed acceptance definition postulates that acceptance is “the degree to which an individual intends to use a system and, when available, to incorporate the system in his/her driving”.

The results from the pilot test, applying the Unified Theory of Acceptance and Use of Technology (UTAUT) in the area of driver support systems, supported to some extent the use of this model as a framework to assess acceptance of a driver support system, but the explanatory power of the model was only twenty percent. The controlled experimental design led to similar experiences among the drivers and hence a limited variance in the data. Additionally, the amount of data was very limited; data was available for 38 drivers. Considering this, the relatively small explanatory power is not surprising. Future studies, with more participants and a targeted experimental design for the continued investigation of the UTAUT model, have to be conducted to be able to possibly find a larger explanatory power.

The pilot test highlighted the importance of ‘social influence’ for ‘behavioural intention’ but did not verify the significance of ‘effort expectancy’ reported by e.g. Venkatesh et al 2003 and Chang et al [64]. This may be a consequence of the small amount of data that was available for the pilot test, or due to improper assessment of the construct in the context of driver support systems. However, the context of computer use, for which the UTAUT model was developed, differs from the context of using driver support systems (driving). Driving demands interactions with other road users and is therefore by its nature a task with a strong social dimension. The importance of ‘social influence’ as a predictor of ‘behavioural intention’ in the context of a driver support system could be a consequence of this. Further, the effort associated with the use of e.g. a computer program and the use of a driver support system may be different. Employing a computer program normally demands actions by the user, while a driver support system normally runs without requiring input from the driver, informing/warning the driver only when there is a need to do so.

The pilot test showed a methodological problem with the "translation" of the items, which were used in information technology to assess constructs in the UTAUT model, into the area of driver support systems. The items used were adopted from Venkatesh et al. [23] as closely as possible. However, for two of them ('Using the system increases my productivity', and 'If I use the system, I will increase my chances of getting a raise') it did not make sense to keep the original wording in the context of a driver support system. These two items also showed validity problems and were excluded from the analysis after the factor analysis.

In the pilot test, the item 'Using the system increases my productivity' was replaced by 'Using the system increases my driving performance'. This appeared to be a too vague concept and the factor analysis indicated more resemblance with 'social influence' than with 'performance expectancy'. It is possible that performance expectancy is better assessed through more direct transportation-related effects like travel time and fuel consumption. The item 'If I use the system, I will increase my chances of getting a raise' was translated into 'If I use the system, I will decrease my risk of being involved in an accident'. These two items have at least one major difference; while the original item speaks of a reward (raise), the modified item speaks of a lack of negative consequence (accidents). There are seldom rewards given for desired driving behaviour. The analysis implies that traffic safety (absence of accidents) is related to all four constructs ('performance expectancy', 'effort expectancy', 'social influence' and 'intention to use'). This is likely to have its roots in its fundamental importance for the driver, the people around the driver, and the authority. It is possible that items dealing with avoiding fines or self appraised rewards, such as enjoyment, comfort, image etc, may be more specifically related to this dimension of 'performance expectancy'.

The results indicate the need to investigate whether the items capture the 'essence' of the constructs when applied to driver support systems, both when "translations" of the items are needed and when not. It seems that some of the items are relevant, and that other items are 'polluting' the constructs with irrelevant information. However, it is important to remember that these results are based on one, quite small, data sample. It is possible that the results might be different in another data set, suggesting other items to be the more relevant. A construct, assessed by several items, is therefore likely to be more robust than using single questions when modelling acceptance. The work on identifying and assessing the constructs should be continued.

Further research is needed to continue the investigation of whether the UTAUT could be a productive model through which to view acceptance of driver support systems. This research should particularly address how the constructs should be measured in the context of driver support systems, and special attention should be given to 'performance expectancy'. Further work is also needed to examine the role of moderators in this context. To accomplish this, more extensive studies, with significantly larger numbers of test subjects and targeted experimental design, are necessary.

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