Driver acceptance of in-vehicle information, assistance and automated systems: An overview

Burnett, Gary and Diels, Cyriel

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Abstract

This chapter provides an overview of Human Factors issues relevant to the acceptance by drivers of technology-based systems within vehicles. A distinction is made between issues relevant to systems providing information to support driving-related tasks (e.g. navigation), systems that provide some degree of control-based assistance (e.g. Adaptive Cruise Control) and those systems which automate the driving task (e.g. platooning). It is recognised that a range of Human Factors issues will have a direct influence on the acceptance of these systems, including those related to distraction, trust and reliability. Moreover, it is apparent that acceptance itself will impact on system usage, primarily raising issues of reliance. The chapter concludes by highlighting some topics which have received relatively little consideration, but will be critical for the ultimate acceptance of in-vehicle systems.

1. Introduction

It is widely acknowledged that vehicles are experiencing a revolution in design as increasing amounts of computing and communications technologies are being introduced within everyday driving situations. Many technologies are utilised, but from the driver's perspective, s~~S~~ystems can be classified into three broad categories:

1. ~~as those~~Systems that provide information or warnings of relevance to the driving task (e.g. ~~vision enhancement,~~ navigation, traffic and travel, driver status monitoring, lane departure warnings)
2. ~~or~~ Systems that aim to assist the driver in fundamental, and specific vehicle control tasks (e.g. adaptive cruise control, collision avoidance, intelligent speed adaptation)
3. Systems that ~~/~~replace the driver in a range of vehicle control tasks, ultimately automating driving (e.g. platooning, driverless cars ~~fundamental vehicle control tasks (e.g. adaptive cruise control, collision avoidance, lane keeping~~).

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In addition, it is important to note that a range of systems provide information and services related to other salient goals:~~,~~ for instance, for comfort/entertainment purposes or to enhance working productivity (e.g. email/Internet access). These systems are important

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in terms of the impact they can have on primary driving tasks (distraction, behavioural adaptation, etc.).

The acceptance of such technology by end users (predominately drivers and their passengers) is important for several reasons. Firstly, and perhaps most importantly, systems must be accepted if they are then to be used (a utility argument), such that the fundamental design goals for a system (safety, driving efficiency, and so on) have the potential to be met. Secondly, an understanding of acceptance is required when considering the closely related issues of usability and satisfaction (see also the chapter by Green and Jordan; and Stevens and Burnett ~~X~~). As noted by Faulkner (2000), there is no universal view on how these various 'soft' terms should be defined, but it is clear that they impinge on each other. Finally, acceptance is highly relevant to key issues of trust and reliance for in-vehicle technology (see also the chapter by Ghazizadeh and Lee). When new systems are wholly accepted, trust levels may be overly high and there may be a mismatch between objective and subjective levels of reliability for a system. Consequently, complacency effects may arise (e.g. following instructions from a navigation system when it is inappropriate to do so). Conversely, a system considered unacceptable to users may be deemed untrustworthy and may be used in an inappropriate fashion (misuse effects). Such behavioural adaptation is a common result of new technological interventions within an overall system~~s'~~ perspective (Wickens et al., 2004).

Considerable data ~~has~~ have been collected by the research community relating to the acceptance of in-vehicle information, ~~and~~ assistance and automating systems. This chapter sets the scene for subsequent chapters in this section by highlighting the breadth of studies that have been conducted. In particular, we will discuss acceptance issues for three distinct example systems:~~,~~ vehicle navigation (information);~~,~~ adaptive cruise control (assistance); and platoon driving (~~assistive~~automating). In these three types of systems, ~~where~~ there are considerable differences in the maturity and adoption of the technology. Moreover, the level of automation associated with the technology rises with each subsequent example, leading to differences in the fundamental Human Factors issues of interest. As a consequence of such variation,~~,~~ the nature of research and conclusions that can be drawn ~~are~~can be ~~fundamentally~~ expected to be significantly different. ~~Future issues in this area will be highlighted.~~

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2. Acceptance issues for specific systems

2.1 Vehicle navigation systems

Vehicle navigation systems are an example of a ubiquitous information technology where there has been considerable Human Factors research both before and after widespread implementation (e.g. Ross et al., 1995; Forbes and Burnett, 2007). These systems aim to support drivers in the strategic and tactical components (planning and following routes, respectively) of the driving and navigating task. They have become increasingly popular in recent years, across many countries, as costs have reduced and the technology has

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matured. Three broad types of system now exist each with their own distinct advantages and disadvantages:~~;~~

1) o~~O~~riginal equipment manufacturer (OEM) systems (integrated within a vehicle);
2) p~~P~~ersonal navigation devices (PNDs - nomadic devices, designed specifically to support navigation); and
3) s~~S~~martphones (multi-functional, small screen devices which possess navigation functionality).

There has been an evolution in design of these systems since the 1990s~~ in this area~~, reflecting technological advances as well as acceptance issues for users. Originally, navigation systems used by drivers were wholly OEM solutions. More recently, PNDs have been dominant, reflecting consumers' desires for affordable, dedicated and portable devices. Nevertheless, this situation is changing as increasingly people exploit the convenience of navigation functionality within a smartphone device. Indeed, there is now some linking between system types as vehicle manufacturers have developed Human-Machine Interfaces (HMIs) which can adapt an in-vehicle system to account for the presence of a smartphone (e.g. by utilising the preferences stored on a smartphone but presenting information within the vehicle according to an OEM solution (larger display, in-vehicle speakers, steering wheel controls, etc.). For current trends in navigation system design, see http://www.autoevolution.com/newstag/satnav/.

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Considerable literature has focused on the human-centred design issues for vehicle navigation systems (see reviews by Srinivisan, 1999; and Burnett, 2009. It is evident that the majority of research in this area ~~has made very convincing safety arguments, assuming~~assumes that issues of distraction and excessive workload are the most likely concerns that navigation system designers must be aware of. The fundamental supposition is that acceptance will not arise unless basic safety concerns are accounted for. Previous ~~A~~authors have noted that driving is already a complex, largely visual, task and navigation system HMI designs will be associated with divided attention and additional information processing (Srinivisan, 1999; Moriarty and Honnery, 2003). Consequently, there is potential for drivers to make fundamental errors whilst engaging with a navigation system, such as failing to observe in time a lead vehicle slowing down or wavering out of lane (Green, 2007).

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~~Therefore~~~~Consequently, t~~There is considerable literature (especially from the 1980s and 1990s) focusing on the distraction effects of navigation systems (visual, auditory, cognitive and biomechanical) and several influential design guidelines handbooks have been produced, informed by research studies with this focus (e.g. Ross et al., 1995; Green et al., 1997; Campbell, Carney and Kantowitz, 1998). These handbooks provide a wide range of guidance for designers concerning issues as diverse as the choice of modality for interfaces, the content and timing of voice messages, display position, colour combinations, font types/sizes, orientation of map displays, and so on. Clearly, such handbooks can be important source documents for Human Factors professionals in industry wishing to argue a case for a specific HMI.

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Based on the authors’ understanding of the content of these handbooks, it is tempting to speculate ~~It is clear that~~that many of the current vehicle navigation HMIs have been influenced by the ~~content of these handbooks~~available guidance. In particular, many vehicle navigation systems ~~largely aim~~are clearly designed to make the workload associated with the navigation task low. This is often achieved using simple turn-by-turn instructions given in the auditory modality, combined with predominantly arrow-based graphics and distance-to-turn information. In some respects, this could be argued as a success for Human Factors research. Studies were conducted (often on public roads, but occasionally within simulators) to provide the ‘believable’ empirical data for guidelines; which, accordingly have informed best practice (e.g. Burnett and Joyner, 1996; Dingus et al., 1989). Unfortunately, however, as a result of the recent mass uptake~~ and clear acceptance of the technology~~, additional issues have come to light that impinge on safety/comfort, routing efficiency, and ultimately acceptance, but may be of larger concern to drivers than distraction. In particular, two key issues relating to the automation effects of navigation systems have been found to be significant, which can be considered broadly under the headings of reliability and reliance.

Reliability

Surveys, in conjunction with considerable anecdotal evidence, have demonstrated the problems associated with unreliable guidance information from vehicle navigation systems. The resulting problems have obvious safety implications (e.g. when a driver turns the wrong way down a one-way street) and can have a considerable impact on the efficiency of the overall transport system (e.g. when a lorry gets stuck under a bridge).

Forbes (2009) (also reported in Forbes and Burnett, 2007) conducted a survey of 872 navigation system owners, which established that 85% had received inaccurate guidance. When asked about guidance that was considered dangerous/illegal, 23% of respondents admitted to obeying the instructions on at least one occasion. Importantly, there was a clear relationship with age, such that older drivers were more likely to follow the unreliable guidance than their younger counterparts.

From an acceptance perspective, it is most interesting to consider here (~~: ~~a) why certain individuals are prone to following such instructions~~,~~ and (b) which characteristics of the HMI can contribute to the problem. This is an area around which there has been very little research to date. With respect to the former question, Forbes (2009) ~~conducted~~ employed detailed follow-up ~~detailed~~ diary studies with 30 navigation system users and used the data to hypothesise that, for certain drivers in specific situations, a *trust* explanation could be given. Specifically, there was evidence for over-trust (or complacency);~~,~~ that is, ~~they~~ drivers saw the relevant road sign/cue, but chose to ignore it and favour the navigation instruction. In other contexts, there was evidence ~~that~~ for an *attention*-based explanation~~ could be put forward~~, since drivers did not believe they saw or processed the relevant road sign/cue. In these cases, it is possible that characteristics of the system user-interface disrupted drivers’ normal allocation of attention. More recent work conducted by Large and Burnett (2013~~2~~, in press) considered these issues in a driving simulator context using eye tracking and confirmed objectively that two distinctive mechanisms are involved in this problem. For system acceptance, each of the

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mechanisms is likely to effect where drivers place the blame for their routing errors (agency) – either with themselves, the system or the surrounding road infrastructure.

Reliance

A further issue concerns drivers' long-term dependency on navigation systems, an outcome explicitly linked to ~~;, that is, situations where there might be~~ overly high levels of system acceptance (Burnett, 2009). Specifically, it has been noted that current technology automates core aspects of the navigation task, including trip planning (where the user's role is essentially to confirm computer-generated routes) and route following (where users respond to computer-generated filtered instructions) (Adler, 2001; Burnett and Lee, 2005; Reagan and Baldwin, 2006). As a result, drivers are largely passive in the navigation task~~,~~ and, consequently, fail to develop a strong mental representation of the space in which they are travelling, commonly referred to as a cognitive map. Several empirical studies have demonstrated this effect for drivers (Jackson, 1998; Burnett and Lee, 2005).

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Several authors have provided convincing arguments as to why this issue is of concern (Burnett and Lee, 2005; Jackson, 1998). Specifically, it is noted that the following advantages exist for individuals who possess a well-formed cognitive map of an environment:

- Enhanced navigational ability – such people are able to accomplish navigation tasks with few cognitive demands based on their own internal knowledge. Indeed, it should be possible in certain environments (e.g. one's home town) to navigate using automatic processing, that is, with no conscious attention.
- Increased flexibility in navigation behaviour – informed individuals have the capacity to choose and then navigate numerous alternative routes to suit particular preferences (e.g. for a scenic versus efficient route), or in response to unanticipated situations (e.g. heavy traffic, poor weather, system failure or absence).
- Social responsibility – a well-formed cognitive map provides a wider transport efficiency and social function, since it empowers a person to navigate for others, for example, by providing verbal directions as a passenger, pedestrian, or over the phone, sketching maps to send in the post, and so on (Hill, 1987).

This is essentially a complex trade-off problem. Notably, there is a conflict between the need to design navigation HMIs which enable an individual to acquire spatial knowledge (*active* navigation) and those which minimise the demands (or workload) of navigating (*passive* navigation). In this respect, authors have noted the potential for active, learning-oriented, HMIs for vehicle navigation systems, as an alternative to the current passive styles (Burnett and Lee, 2005). Such interfaces would aim to provide navigation information in a form ~~which~~ that ensures that the demands of the navigation task in wholly unfamiliar areas are at an acceptable, low level, whilst aiming to support drivers in the cognitive mapping process. In essence, these interfaces would aspire to move people onwards through the various stages of cognitive map development, ultimately to a level in which they are able to navigate effectively for themselves and others, independent of any external information. Some initial progress was made on this topic in a simulator study conducted by Oliver and Burnett (2008).

2.2 Adaptive Cruise Control (ACC)

Adaptive Cruise Control (ACC) is an example of a driver support (assistance~~ive~~) system which has been in production for several years. To this date, however, ACC is only offered as an optional feature in the luxury vehicle segment and the penetration rate is low as a consequence. ~~, but is not widely used within the driving population.~~ Functionally, ACC will maintain a set speed as per conventional Cruise Control systems, when there is no traffic immediately ahead of the driver. In situations where traffic is ahead in the driver's lane, ACC uses radar to maintain a constant time headway to the vehicle ahead. This headway is ~~subsequently~~ kept constant by the system by adjusting the speed of the vehicle to prevent exceeding a pre-defined time gap. First~~-~~generation ACCs require a minimum driving speed of typically 30kph, below which the system is deactivated requiring the driver to take over control below this speed. Similarly, manual control is regained when the driver deactivates the system by pressing the brake pedal. Second~~-~~generation ACCs have been developed that extend the utility of ACCs - by not only expanding the speed range to velocities below 30kph, but also bringing the vehicle to a complete stop and accelerating~~e~~ again if the preceding vehicle does so;~~,~~ a so-called "Stop & Go" function. Notwithstanding these significant system enhancements, ACCs have a limited deceleration level. Hence, under critical driving conditions, such as emergency braking situations, the driver is still required to regain control of the vehicle. It is for this primary reason that ACCs are marketed as comfort systems rather than safety systems.

ACC is predicted to have a number of positive effects. From the driver's perspective, it has already been shown that ACC can reduce workload and increase perceptions of comfort (e.g. Stanton et al., 1997). Furthermore, deployment of ACC is expected to lead to improved traffic safety, roadway capacity and environmental traffic impact (Vahidi & Eskandarian, 2003). That is, ~~safer and s~~shorter time headways as well as smoother acceleration and deceleration profiles help to increase road capacity and traffic flow whereas the minimum time headway adopted by ACC systems eradicate short, unsafe following distances~~; which, in turn, translate into improved traffic safety, roadway capacity and environmental traffic impact (Vahidi & Eskandarian, 2003)~~. However, the extent to which these potential advantages materialise will be largely dependent on penetration rates which, at least for Europe, are predicted to be low in the foreseeable future - around 10% in 2020~~-~~ (Wilmink et al., 2008). A major factor in future deployment will be drivers' acceptance and willingness to engage with ACC systems.

User acceptance of ACC has been studied using a wide range of methods including interviews, questionnaire surveys, simulator experiments, and field operational tests (FOTs). As part of the PROMETHEUS project, one of the earliest ACC acceptance studies was conducted by Becker et al. (1994) in which participants drove around in real traffic with prototype equipped vehicles. Results showed that ACC was perceived as a comfort-oriented and safety-enhancing driver assistance system. Overall, ACC was well received by participants and considered acceptable, comfortable, safe and relaxing. Similar results were obtained in a driving simulator study by Nilsson (1995) in which

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ACC was felt to add comfort and convenience to the driving experience. Fancher et al. (1995) conducted a field trial which showed that in comparison to conventional cruise control, ACC was perceived as more comfortable as it required fewer interventions. In dense traffic conditions, however, users tended to turn off the ACC as the system-defined headways were perceived to be too large resulting in other traffic cutting in.

Although these early studies suggest a high level of system acceptance, it is worth noting that acceptance may not be uniform across all users and may also depend on users' needs and motivations. For example, Hoedemaeker and Brookhuis (1998) investigated ACC user acceptance as a function of users' driving style and found that, whereas ACC was perceived positively in terms of workload, comfort and usefulness, participants who liked to drive fast, as assessed using a driving style questionnaire, were less positive about ~~ACC~~it.

In 2005, the National Highway Traffic Safety Administration (NHTSA) in the US reported the results of the Automotive Collision Avoidance System field operational test (ACAS FOT) program (NHTSA, 2005). The FOT involved a 12~~-~~-month~~s~~ period in which 11 cars equipped with ACC and Forward Collision Warning (FCW) were driven under natural conditions by a total of 96 participants. Each participant drove an equipped car for several weeks after which system acceptance was assessed using a combination of questionnaires, interviews, and focus groups. Again, system acceptance was high with three quarters of participants intending to purchase an ACC system if they were buying a new car. When considering individual driver characteristics including age, gender, education, and income, it was found that age was the best predictive factor, with older drivers reporting highest system acceptance. Notwithstanding the high acceptance levels, a number of ACC design characteristics were thought to benefit from future improvements. In particular, the maximum ACC speed and shortest available gap setting were considered too low. Some participants also mentioned the need to manually interfere due to the slowness for the system to decelerate and, conversely, pick up speed in overtaking manoeuvres.

Similar to the ACAS FOT, Alkim et al. (2007) reported the results of a Dutch field study which investigated drivers' use and acceptance of ACC, Lane Departure Warning (LDW), ~~and~~ Headway Monitoring and Warning (HMW)~~,~~ and Lane Keeping Assistance (LKA) systems. Again, ACC ~~again~~ enjoyed a high acceptance level. It further showed that the active assistance or intervention systems (i.e. ACC and LKA) enjoyed a higher level of acceptance than the warning systems (i.e. LDW and HMW). As pointed out by the authors, this was an unexpected finding given that drivers usually indicate a preference for an informative system rather than a system that takes over parts of the driving task. This difference in acceptance may be ascribed to the fact that the benefits of warning systems were not only perceived to be less apparent, but there was also a lack of system trust due to the high number of false ~~triggers~~ alerts the systems produced. Furthermore, Alkim et al. (2007) findings that users are more positive after actual experience with such systems compared to a priori expectations ~~pointed out the discrepancy between "preferences" that are based on experience or expectation,~~clearly

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illustrates~~ing~~ the point that the manner in which acceptance is evaluated (~~,~~ i.e. interview, on-road studies)~~,~~ affect users' perceptions and attitudes.

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Most recently, Larsson (2012) conducted a questionnaire survey amongst 130 ACC owners regarding their daily use and experience. ~~Acknowledging the study's~~The study was limited in ~~limitation~~ that it ~~only~~ included only a specific ACC system. The ~~, the~~ results are nevertheless of interest and point towards some acceptance issues that have been consistently reported within the literature. These can be categorised as being either system limitations or communication errors. Regarding the latter, nearly a quarter of respondents indicated that they had forgotten at some point whether ACC was engaged and were subsequently surprised to find the vehicle braking or accelerating. This "mode error", whereby the driver believes the system to be in one mode when it is actually in another, may not only negatively affect system acceptance but may also compromise road safety, as the unexpected vehicle behaviour may result in inappropriate or ill-timed driver responses. As pointed out by Larsson (2012), the occurrence of mode errors suggests that future systems would benefit from improved interface designs. The main factors affecting ACC acceptance, however, appeared to be related to system limitations. In particular conditions in which radar contact was either lost (e.g. steep hills, sharp curves, roundabouts, exiting a motorway), or in which latches onto traffic in adjacent lanes led the vehicle to change its speed inappropriately, were found to frustrate users. In addition, a recurrent complaint was the slow system response in picking up speed when changing lanes to overtake a vehicle.

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Whereas the above mentioned system limitations clearly are detrimental with regard to user acceptance, it ~~should~~ can be concluded ~~be noted~~ that, overall, ACC enjoys a high level of user acceptance and is ~~is a driver assistance system that is generally~~ regarded to significantly enhance drivers' comfort~~highly accepted~~. ~~Furthermore, f~~Future system enhancements such as the incorporation of GPS, vehicle-to-vehicle, and vehicle-to-infrastructure data, as well as information on the driver's intentions (e.g. use of indicator) can be expected to eliminate or minimise current systems' limitations (e.g. Sol et al., 2008), ~~ultimately~~ improving user acceptance even further.

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2.3 Platoon driving

Platoon driving is an example of a future technology where the Human Factors acceptance work is more speculative and usually simulator-based. Platoon driving, also referred to as platooning or road-trainings~~s~~, can be viewed as a logical next step in road transport automation. It refers to the grouping of vehicles maintaining a short time headway achieved by using a combination of wireless communications, lateral and longitudinal control units, and sensor technology. Although different future platoon implementations can be envisaged (e.g. Martens et al., 2007), current concepts assume a system whereby the platoon is led by a trained, professional driver whilst the following vehicles are driven fully automatically by the system (Robinson et al., 2010; Lank et al., 2011). Compared ~~to~~ with ACC, platoon driving is extending the automation of the driving task considerably by adding lateral vehicle control which, in essence, leaves the driver free to relax or engage in non-driving tasks.

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Platoon driving is predicted to provide a range of advantages (see Robinson et al., 2010; Lank et al., 2011). First, the small headways maintained in platoons result~~s~~ not only in a reduction in drag and associated energy efficiency, but also an increase in road network capacity due to the mere fact that less road space is required. A knock-on effect is that overtaking manoeuvres by other road users can be performed more quickly resulting in a more homogeneous traffic flow. Safety benefits are also expected: ~~—~~unlike drivers, the automated system does not suffer from distraction~~,~~ ; and, secondly, the automated ~~system's~~ reaction times of the system are only a fraction of ~~the~~ human responses times. Finally, the fact that the driving task is entirely taken over by the system is expected to result in enhanced driver comfort.

Regardless of the already proven technical feasibility as well as ~~the~~ anticipated benefits (Lank et al., 2011), the success of platooning will ~~ultimately~~ depend ultimately on road users' as well as societal ~~'~~acceptance of the system. Compared to ACC, platooning creates a considerably more complex situation where we not only have to take into consideration the driver within the platoon, but also road users' driving in their vicinity (Gouy et al., 2012). With regards to the former, there are some significant human factors challenges (see Larburu et al., 2010; Robinson et al., 2010; Martens et al. 2007). Taking the driver out of the loop raises questions about the effects on drivers' situational awareness, or their knowledge of the surrounding traffic and prevailing conditions. In particular t~~T~~his may become a safety issue when the driver is required to switch from autonomous driving to normal driving or when responding to ~~, when respondingis required to respond to~~ unexpected events due to system breakdowns~~, is engaged in secondary tasks, or is experiencing underload~~. With the driver effectively becoming a passive monitor, the design of the human-machine interface will become a critical aspect for the success of such systems. In addition to these safety issues, user acceptance of platooning will depend on the extent to which the system is perceived to be accurate and reliable and its use to be considered both safer and more comfortable compared to normal driving.

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As mentioned, the presence of platoons on normal motorways also creates an entirely new set of driving conditions for non-platoon road users. Although the exact consequences will be dependent on the specific design of platoons (~~,~~e.g. what is the maximum number of vehicles; are vehicles allowed to leave or join a platoon from the side; ~~(~~see Robinson et al., 2010), for platooning to be acceptable it is important that the presence of platoons on normal motorways does not lead to actual or perceived negative consequences. Platoons may interfere with other road users in a number of ways. For example, entering and exiting a motorway and overtaking may be perceived to be less safe and more demanding. Also, what are the effects of the shorter time headways adopted in platoons? Could this result in behavioural adaptation whereby non-platoon drivers consciously or unconsciously also adopt shorter time headways possibly compromising road safety? Initial simulator studies on this topic have shown evidence for such effects (Gouy et al. 2012). These are only some of the type of questions that need to be answered to better understand the effects of platooning in the context of acceptability.

The first few studies have now been undertaken to start to better understand some of the above issues. The German national project KONVOI set out to conduct simulator and on-road testing of platoons consisting of coupled trucks (Lank et al., 2011). The platooning concept required the first driver of a platoon to manually control the truck with the other trucks following the lead truck fully automatically. To join a platoon, the driver was required to send a request via a touch screen when within 50 metres of the platoon. Following acceptance by the platoon lead vehicle, automation would set in and gradually close the gap to a distance of 10 metres from the truck at the end of the platoon. Similarly, to de-couple and leave the platoon, the driver would be sent a request and, following acknowledgement by the lead vehicle, the time headway would increase again to 50 metres followed by a visual-auditory countdown signal to indicate the end of the automated drive.

Within in the KONVOI project, user acceptance was evaluated in three phases, starting out with focus groups, followed by simulator studies and on-road studies (Lank et al., 2011). This allowed for a clear demonstration of the effect that experience with a new technology might have on user acceptance. Before any actual experience with platoon driving, the initial focus groups revealed 80% of the truck drivers to have a negative attitude towards the concept of platooning. However, following actual experience of platooning, a considerable shift was observed with an ultimate approval rate of 54%.

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System acceptance of non-platoon drivers was evaluated in a subsequent driving simulator study. Although some concerns were raised that platoon driving might lead to additional driving demands for some, the vast majority of drivers (80%) showed a positive attitude towards platooning and thought of it as a sensible development. Platoons were regarded ~~to~~ as reducing~~e~~ driver workload, in part due to the reduction in the number of overtaking manoeuvres required, and drivers expressed a preference for overtaking a platoon as opposed to individual trucks. On the other hand, concerns were raised regarding the additional demand and responsibility put on the driver of the lead vehicle. System over-reliance and subsequent inattention was feared to result in "illusionary safety" and possibly increased accident risk. Although drivers reported little difficulties entering and exiting the motorway in the presence of platoons, the additional complexity of the traffic conditions was mentioned as possible reasons for lower acceptance levels by other road users. Respondents also mentioned the need for international standardisation regarding the legal length of platoons and the full development and testing before market deployment.

Most recently, user acceptance of platoon driving has been evaluated as part of the European project "Safe Road Trains for the Environment (~~,~~ SARTRE)~~"~~. Larburu et al. (2010) conducted a simulator study to assess drivers' responses to platoon driving. Again, acceptance was not only assessed from the perspective of the platoon driver but also from drivers encountering a platoon. The study evaluated various platoon configurations that varied in length and headways, and also included a prototype HMI which was incorporated to inform the driver during transition stages from manual to automatic driving, and vice versa. From a user acceptance perspective, the study showed some consistent gender effects with female drivers reporting to be less tolerant of shorter time headways when driving within the platoons then men. It was also found that the inter-vehicle distance at which participants reported to feel uncomfortable (16m) was well above the distance at which platoons are considered to become energy efficient and safe (Larburu et al., 2010). Acknowledging the inherent limitations of this~~is~~ kind of study~~ies~~ (~~,~~ i.e. the lack of participants' experience and familiarity with platoons)~~,~~ these results illustrate the need for future studies to better understand the acceptability of short time headways. Regarding the HMI design, the provision of information during transition changes was considered imperative with a vast majority of participants referring to the need to include a driver acknowledgment step before starting a coupling or de-coupling manoeuvre.

When asked about their experience driving in proximity to a platoon, platoon length was one of the key parameters that affected users' acceptance. Whereas driving next to a 5 vehicle ~~-~~long platoon was perceived to be similar to normal driving, safe and not to cause any difficulties performing manoeuvres (e.g. exiting motorway), this was no longer the case with a platoon length of 15 vehicles. ~~Even l~~L~~onger p~~Platoons of ~~25~~ vehicles longer than 25 were deemed unacceptable by 90% of participants, suggesting this to be a maximum acceptable platoon length.

In summary, the results of the studies conducted so far indicate that platoon driving may become a near future reality. From a technical perspective, there are no barriers that would prevent such systems to be implemented. However, these same studies also highlight several human factors and acceptance issues that require a better understanding before widespread introduction is feasible. Beyond obvious liability issues, system acceptance will be dependent on platoon configurations, protocol for transferring control between driver and vehicle, HMI design, system failure management procedures, as well as non-platoon drivers' interaction with and response to platoons. These fundamental questions require significant research efforts to provide the necessary empirical support before road authorities will be sufficiently confident to allow for platoon driving. ~~into platoon driving conducted so far suggest that there are no initial barriers to the employment of platoons, both from the perspective of platoon drivers or road users driving in the vicinity of these platoons. However, platoon driving is still in the developmental stage and numerous human factors issues remain to be investigated that are related to platoon configurations, the design of the HMI, drivers' responses to system failures, and switching control.~~

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3. Overall discussion and conclusions

This chapter has raised a wide range of acceptance issues for in-vehicle technology by considering example systems according to their impact on the driving task, as well as their current level of maturity. It is clear that a broad range of automation-related effects are closely aligned with acceptance issues, whether dealing with information or assistance systems. For instance, issues concerning reliability, reliance and trust will be rich areas for future research. Whilst it is likely that the capabilities of these systems will increase with customer demand, it is unlikely that they will ever be 100% reliable. Importantly, research from other application domains (e.g. process control) indicates that people find it particularly difficult to calibrate objective with subjective reliability when systems are close to perfect (Wickens et al., 2004). So, for example, if a system is objectively 99% reliable, users are prone to treat it as 100% reliable and may well adopt complacency-related behaviours accordingly.

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Moreover, it is worth emphasising that different in-vehicle technologies~~y systems~~ will not be used independently, but in combination with each other. Research studies generally neglect this fact and consider the impact of drivers interacting with single systems. In reality, for ~~the complex~~many real-world driving situations there will be considerable interaction effects. For instance, a vehicle equipped with a system that automates longitudinal and lateral control of the vehicle (such as platooning) is likely to have a significant effect on the tasks that drivers are willing to undertake with other systems, e.g. those providing entertainment or productivity services. How drivers will trade-off the various tasks that occur in future cars will be critical questions for research. In particular, the acceptance or otherwise of the different systems will have a profound effect on how they might be used as an integrated whole.

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As a final point, it should be noted that the vehicle often incorporates a social environment when passengers are present, or even when communications are conducted with people remote/external to the vehicle (e.g. via a phone link~~, with pedestrians~~). Previous research concerning acceptance issues ~~largely~~ focus largely on the driver solely as an operator of the vehicle. In reality, the social context will also have a considerable impact on users' attitudes, behaviour and performance with new technology in ~~the~~ many highly dynamic and complex driving situations. As an example, a recent study by Large and Burnett (2012) noted how the presence of passengers affected a driver's interactions with a navigation system, particularly related to the acceptance of voice instructions.

Comment [MR42]:

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