Potential challenges facing persons-in-charge of automated buses, and means of recruiting, testing, and training them

An evidence review

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Summary

Whilst promising many benefits, widespread private automated vehicles also hold potential to increase traffic flows, worsen congestion, worsen public health, and reduce public transport use (Ainsalu et al., 2018). At the same time, there is potential for public transport, its users and providers, to benefit from automation, through safety benefits and reduction of costs of first and/or last mile travel. Recruiting, testing, and monitoring ‘persons-in-charge’[1] who can supervise, (and drive if necessary,) automated buses will be a vital component in making such operations viable. This document is intended as a source document for the MultiCAV project, in respect of issues connected with the person-in-charge. It addresses a gap in knowledge by bringing together evidence in four main foci:

1) What are the challenges for the person-in-charge, and therefore which corresponding aptitudes and characteristics of the person-in-charge are likely to be important to test?

A primary challenge for persons-in-charge is likely to be maintaining attention. Tentative solutions to keep persons-in-charge in the loop include periods of manual control, appropriate feedback from the automated system to the person-in-charge, and appropriate alerts for initiating human takeover, which are neither too rare nor too (unnecessarily) frequent. Such solutions are particularly important in the context of the person-in-charge taking control back from the automated system.

2) What relevant tests, training and standards, already exist for automated road vehicles.

Some private enterprises are already offering driver training for automated vehicles, although open on-line details about these courses was sparse. A consortium of large car manufacturers has developed agreed best practice for automated trials, and the UK’s Department for Transport (DfT) has produced a code of practice for automated trials (DfT, 2019). There may be important differences between guidance for trial situations as opposed to commercial services. These include commercial services requiring long shifts, risking degradation of employees’ skills over months and years, and ideally using better functioning vehicles than trials.

3) What challenges do non-automated bus drivers face (attention, fatigue etc.) and how are these drivers recruited and tested? Similarly, how are train drivers recruited and tested?

Resilience of character appears important for drivers of non-automated buses, given the stresses of the role. Fatigue was identified as a specific challenge that bus drivers face. Information about the application and training process for drivers of non-automated buses, for First and Stagecoach companies, was reviewed. However, in addition to this information, there is likely to be more detail provided to applicants in training. The process of both companies involves specific background checks, an initial assessment day, a main training period of around three weeks, and a period of driving real routes in the company of a mentor or ‘buddy’.

A wide range of aptitudes are required, and tested for, in train drivers. Including abilities in the areas of driving skills, understanding the vehicle, reacting to the environment beyond the vehicle, wider cognitive abilities and responsibility in relation to safety.

[1] ‘Person-in-charge’ denotes the on-board operative of the automated bus. The Law Commission and Scottish Law Commission (2018) use the term ‘user-in-charge’ to differentiate from a driver or supervisor, but the user-in-charge must be able to take over driving. We have substituted ‘person’ for ‘user’ because ‘person’ can imply a paid employee, whereas a ‘user’ does not.

4) What part can simulation play in assessment? What differences are there between simulated assessment and real life?

Many academic studies have been conducted into simulation. Simulations can simultaneously collect different types of data relating to eye movements, mental models of automated systems, and driving capability. Simulation has also been used to measure fatigue. The method has been found to be effective for training persons-in-charge of automated vehicles. Simulation may modify attitudes towards automation, even when not primarily designed to do so. The strengths of using simulations as a method of training include participants tending to take the whole process of training seriously. Weaknesses relate to differences between simulations and real-life running.

The document also includes a summary of psychometric tests relevant to testing persons-in-charge, in Table 3, at the end of the document.

Introduction

Research on automation to date has focused disproportionally on private rather than public vehicles (Azad et al., 2019) and when it has addressed public transport, this has tended to be automated shuttles rather than full-size buses (see Ainsalu et al., 2018). Substantial uncertainties still remain then around the potential impact of automated buses due to lack of evidence (Janmaat, 2019). Studies identified by Azad et al., (2019) around (mainly smaller sized) automated buses, has mainly been conducted in Europe, with half of these being related to the CityMobil2 project. Research studies in the USA, were less numerous than in Europe, and were more likely to be simulation based.

The search for evidence was based on the rapid evidence review model of undertaking literature searches. Useful questions to answer were decided by UWE's MultiCAV research team. This led to search terms being used to identify sources, based around the areas of:

- challenges with automated vehicle operation;
- use of simulation in connection to automated vehicles;
- recruitment and performance of drivers of non-automated buses;
- trials versus real services; and
- ongoing monitoring of safety drivers.

Evidence was sought using Google, Google Scholar, and the UWE Library search engines. Some sources were also included from an earlier literature search. Other individual pieces of literature were also included where these were known to the authors.

1) What are the challenges for the person-in-charge, and therefore which corresponding aptitudes and characteristics of the person-in-charge are likely to be important to test?

Attention, fatigue and stress.

Automation of road vehicles can require the person-in-charge to monitor the automated systems (Waard et al., 2010). Hence, ability to maintain attention when monitoring systems could be an important attribute of a safety operative, and inattention an important risk. In the case of automated navigation, (Casner et al., 2016) discuss different forms of inattention that can accompany automation, including the feeling that an automated process does not require attention, disengagement and passivity. Automation can also lead to persons-in-charge paying more attention to automated alerts than to the situation that has triggered the alert.

Passive monitoring of automated processes can be difficult (Molly and Parasuraman, 1996, cited by Waard et al., 2010) and stressful (Hancock & Parasuraman, 1992, cited by Waard et al. 2010) for human beings to maintain. Vigilance during tasks such as air traffic control, military surveillance, industrial quality control or long distance driving, has been found to decrease within the first fifteen minutes of the task, but can even diminish during first five minutes (Teichner, 1974, Helton, Dember Warm & Matthews, 2000, and other sources, cited in (Warm et al., 2008) There is debate over whether attention declines during such vigilance tasks, due to under-stimulation leading to a withdrawal of attention, or due to imposing significant demands on the mental processes of the observer. Warm et al., reviewing behavioural and neural measures in previous studies, support the position that it is in fact the demands of vigilance, rather than its easiness, which cause reduced performance.

The problem of persons-in-charge of automated systems losing the focus of their attention is often presented in relation to the term 'situation awareness' or through discussion of being 'out of the loop'. Automated running can lead to depleted situational awareness[2] (Ward et al., 1995, cited in Waard et al., 2010, Saffarian, 2012), so a measurement of such awareness after a period of automated running may be important. Another important concept relating to automated systems is humans falling 'out of the loop' due to temporary reduction in the need for their input. Being out of the loop can reduce the ability to intervene in systems or takeover from them where necessary (Kaber & Endsley, 2004, p.114). Delays in responding to a failure in automated systems may be accounted for by time taken by an out of the loop person-in-charge to grasp the state of the system and the situation, and to become aware of what appropriate action they should take.

'Human-centred automation' denotes, amongst other things, designs which keep the human in the loop, in order to maximise human-machine effectiveness (Kaber & Endsley, 2004). Strategies to keep the person-in-charge 'in the loop', include for example periods of manual control (Parasuraman, Mouloua & Molloy, 1996 cited by Waard et al. 2010).

Evidence exists around alerts that automated systems give, with danger arising from these being too frequent and false, which may preclude the confidence of the user, (Parasuraman and Riley, 1997, cited in Law Commission and Scottish Law Commission, 2018). Conversely, if alerts are too infrequent, the user may put excessive confidence in the automation. Alerts should not be startling (Casner et al., 2016) but should convey the need for the person-in-charge to takeover in a manner that is 'easily and clearly understood' (DfT, 2019, p.20). The alert could be auditory, visual or haptic, as appropriate. A display in the vehicle should clearly indicate whether or not the vehicle is in automated mode. Becoming out of the loop may also be mitigated by provision of feedback from the automated system to the person-in-charge. This can help correct a false understanding of automated systems, direct attention, encourage a correct level of trust, and encourage appropriate

[2] Multiple definitions of 'situational awareness' exist. It can be understood as 'an appropriate awareness of a situation (Stanton, Chambers, & Piggott, 2001, derived from Smith and Hancock, 1995). Drawing largely on aviation literature, Stanton, Chambers & Piggott (2001, p.191) review three more detailed definitions that focus on situational awareness being perception and evaluation of 'elements in the environment, 'dynamic reflection' on a situation by an individual, or an unchanging element within the 'agent-environment system' that enables knowledge and behaviour necessary to achieve desired goals. Situational awareness can be measured by the (self-evaluative) Situation Awareness Rating Technique (Selcon and Taylor, 1990.)

intervention (Norman, 1990, Bagheir and Jamieson, 2004, Wickens et al. 2000, Bisantz and Seong, 2001, Cohen, 2000, Moray et al., 2000, all cited in Seppelt & Lee, 2019).

Evidence on automated vehicle running emphasises the danger of driver distraction (Merat & Lee, 2012). In extreme form, this might involve car drivers being tempted to engage in other activities or pastimes during automated running (Rudin-Brown & Parker, 2004, cited in Saffarian et al., 2012). Such 'misbehaviours' have been anecdotally implicated in collisions involving conventional cars with driver assistance systems and experimental automated cars in the US, (i.e., drivers attending to video entertainment rather than monitoring the road and instruments.)

Maintaining attention may result in a person-in-charge experiencing fatigue, which can be physical or mental (SAE mobilus, 2019). A dichotomy of active and passive fatigue has been examined in relation to driving by Saxby et al. (2013). Active fatigue is defined by Desmond and Hancock (2001, p.601, cited by Saxby et al. 2013, p.3) as issuing from 'continuous and prolonged, task-related psychomotor adjustment' whereas passive fatigue arises from 'system monitoring with either rare or even no overt perceptual-motor requirements'. Saxby et al. found active fatigue was associated with 'distress, overload and heightened coping efforts and passive fatigue was associated with 'large-magnitude declines in task engagement, cognitive underload and reduced challenge appraisal' (p.287). Importantly it was the passive rather than active fatigue that led to declining ability to brake or steer in response to an emergency event. It could be hypothesised that whereas drivers of non-automated buses may be prone to active fatigue (with Filtness et al., 2019, stating that mental overload was reported in relation to fatigue of London Drivers), persons-in-charge of automated vehicles may be vulnerable to the passive fatigue which is more dangerous in terms of performance failings. Fatigue has been a problem in rail services, with many 'signal passed at danger' (SPAD) events, a type of train driver error, resulting from fatigue or sleepiness (Filtness & Naweed, 2017).

Some of the well-being challenges of supervising automated systems may occur after the shift, with some studies suggesting observers report sleepiness, boredom, irritation or fatigue after completion of a vigilance task (Warm et al., 2008). These resultant states may be measured by questionnaires such as the Dundee Stress State Questionnaire (DSSQ) (Neubauer, Matthews, & Saxby, 2014).

Subjective perceptions of operators of the workload relating to a specific task can be measured by the NASA-task load index (NASA-TLX) (Hart, 2006). This measures perceived workload in the categories of 'Mental, physical temporal, frustration, effort and performance.' (ibid. p.904).

Takeover from automated running

It is particularly important to maintain attention during automated running as sudden takeover from the automation may be required of the person-in-charge. Numerous research experiments have tested the public's ability to take over control of automated vehicles using simulated vehicles (Morgan et al., 2018, Waard et al., 2010, Merat et al., 2014 for example). Meeting this challenge is likely to be important for safe running of automated vehicles (Gold et al., 2018).

Safety of takeover can be dependent on the time taken for the transition. For example, some situations requiring the human to retake control need to be addressed in a few milliseconds only but can take seconds for humans to respond to (Ebnali et al., 2019). The time taken to re-establish human driving, can be conceptualised as 'takeover' the time taken to reengage with the driving task and 'handover' (i.e., time taken to regain a baseline/normal level of driving, Morgan et al., 2018, p.761). Safety of takeover also necessitates the transition being controlled and ordered (SAE, 2018, cited in Law Commission and Scottish Law Commission, 2018). Effective transition is also reliant on effective driving once it is complete. The Venturer experiments, conducted by CTS and partners, used simulated and real automated vehicles to test time taken for a planned handover from automated to manual operation, and the characteristics of the ensuing manual driving. These experiments tested the time taken for the participant to retake control, and also suggested that manual driving behaviour was more cautious, specifically in terms of speed, after the period in automated mode than before (Morgan et al., 2018), this cautious driving has been noted for up to 55 seconds following takeover (Morgan et al., 2018). Potentially then, lack of confidence in alternating between manual and automated modes could be a negative in candidates, although intuitively this would dissipate with experience.

A number of vehicular, environmental and personal factors can affect transition from automated to human running. The time taken can vary by the speed of vehicle, with particular concern attending automated vehicles travelling above 40mph in some urban settings. Traffic density has been found to negatively affect take-over performance (Gold et al., 2018). In relation to the driver, resuming control can be particularly challenging in light of the potential attention fatigue (Neubauer et al., 2014) and complacency (Waard et al., 2010) that can accompany automated running, as discussed above. The age of the person in charge has also been found to somewhat effect performance of taking over control from level three automation (Gold et al., 2018).

Mental models, trust and responsibility

It is important for an aviation pilot to have an effective mental model of the aircraft's automated systems (Sarter et al. 2007). It is likely that persons-in-charge also should have good mental models of automation, as insufficient understanding of what automated systems do can be dangerous (Saffarian et al. 2012). It is through a mental model that a person can explain and predict automated behaviour and take controlling action if necessary (Rouse and Morris, 1986, cited in Seppelt & Lee, 2019). Thus, DfT's code of practice for trials states 'The safety driver or operator should be familiar with and understand the systems under trial, their capabilities and any limitations, and be able to anticipate the need to intervene and resume manual control if necessary' (DfT, 2019, p.15). Level of trust in the automated system is an emotional response accompanying the mental model of automation (Seppelt & Lee, 2019). Level of trust is important to performance (Waard et al., 2010, Ebnali et al., 2019).), with excessive and inaccurate trust, potentially leading the person-in-charge to be passive, or over-reliant (Saffarian et al., 2012, Waard et al. 2010). Psychological scales have been developed to measure individuals' trust in automation, including the Trust in automation state checklist (Jian et al., 2000) and Trust in automation (TiA) Korber (2018). Related to trust, perceptions of how useable a system is can be measured by the System usability scale (Brooke, 1996).

The advent of automated vehicles will raise discussions of legal liability, with regard to when an offence or collision is the responsibility of the person-in-charge, and when it is the responsibility of the automated system (Law Commission and Scottish Law Commission, 2018). Understanding, and handling, the boundaries of their responsibility, would be an important aptitude in the person-in-charge. The Commission, considering private automated vehicles, suggest that persons-in-charge would be legally liable for maintenance, reporting accidents and ensuring children have seatbelts, some of these duties may translate to a public service. DfT emphasises the responsibility of the person-in-charge, during automated trials, for the safety of the vehicle operation at all times, during both manual and automated modes (DfT, 2019). The person-in-charge is responsible to ensure the vehicle complies with traffic laws and must be ready to takeover control.

A specific instance of responsibility for the person-in-charge is making moral judgements that automated systems cannot make (Goodall, 2014). Another responsibility for persons-in-charge, at least until automation becomes commonplace, would be to appear a normal driver, in order to avoid alarming and distracting other drivers (DfT, 2019). Other daily responsibilities for the person-in-charge, proposed in Automated Vehicle Safety Consortium's best practice guidelines may include pre- and post-operation protocols (SAE mobilus, 2019). In a trialling situation, pre-protocols might include the use of checklists, understanding any updates to software or hardware, a vehicle systems check, and possible briefings. Post-protocols may include communications around reviewing performance, reporting on environmental conditions and so on. In relation to trial situations, the DfT highlights that organisations, as well as persons-in-charge, must also bear responsibilities (DfT, 2019). These include, ensuring persons-in-charge are suitable and sufficiently trained, delivering suitable and demanding procedures to ensure this and delivering rules of conduct for persons-in-charge (covering alcohol and drug use for instance).

Driving skills

The level of driving skill of a person-in-charge is important, with only candidates with a driving history that does not cause safety concern being selected (DfT, 2019). The DfT code of practice goes on to state that, if using a public road, a person-in-charge should have both the driving licence but also several years' experience of driving that class of vehicle. After becoming a person-in-charge, atrophy of skill that may accompany automation may be a danger (Casner, Hutchins, & Norman, 2016) (Saffarian, De Winter, & Happee, 2012). This phenomenon would echo skill degradation in pilots using automated systems (Brookhuis & Waard de, 2006), which has been noted as a concern of pilots who use such systems extensively (Waard et al., 2010).

A final range of relevant aptitudes for persons-in-charge can be inferred from the skills necessary in train drivers. An on-line career guide lists these as including: mechanical knowledge, hand-eye coordination, ability to maintain concentration, physical endurance, communication skills including dealing with the public, memory, good reactions, ability to remember and understand regulations and procedures, a calm disposition, ability to take responsibility, and judgement and reliability (My job search, 2020.)

In a neat summary of the above sections, (Ebnali et al., 2019, p.186) sort the abilities that AV driver training has commonly addressed into three categories: procedural skills include 'lower-order cognitive skills' (p.186) which includes steering, braking; higher-order cognitive skills include perceiving hazards accurately, visually scanning effectively and cultivation situation awareness; and insight and attitude include 'trust, acceptance, overconfidence, overestimation of personal skills, self-diagnostic, and safe estimation of distance'. The testing of twenty-five professional bus drivers in a driving simulator led Brookhuis & Waard de (2006) to suggest 'a driving licence issued for conventional driving should not be applied to driving (semi-) automated vehicles unconditionally, at least not without thorough preparation for what may happen in such conditions. From a national law perspective, it may be that new driving licence categories become necessary (Law Commission and Scottish Law Commission, 2018).

2) What relevant tests, training and standards, already exist for automated road vehicles?

To test or encourage the above aptitudes, organisations are starting to provide training and safety standards for automated driving generally (i.e., not specifically for automated buses). CAT driver training is a UK based commercial enterprise which offers 'Autonomous safety driver & operator training' (CAT Driver Training, 2020). This training is offered commercially, alongside a range of other courses such as advanced driving and racing courses. The online course description suggests it covers informing automated vehicle designers of safe driving practices but also addresses those driving the vehicle. Promotional slides from CAT suggest the training includes managing risk, braking techniques, public perception & distractions, risks associated with testing on the public highway, and vehicle safety checks.

The Automated Vehicle Safety Consortium, a group including large car manufacturers, has produced a best practice document addressing the selection and training of test drivers of automated vehicles (SAE Mobilus, 2019). In line with much of the discussion of driver aptitudes above this suggests that persons-in-charge should be able to undertake the following:

- Anticipate a failure in the automation and control the vehicle, should it occur.
- Understand the limitations of the automated system, including sensor limitations for example. This will help in anticipatory takeover of control.
- Be familiar with the capabilities of the vehicle and its automation.
- Have a licence (with no extreme violations) for the vehicle type being used and should have three years' experience of driving at least.
- Pass a driving test related to the automated vehicle in question (in addition to holding a licence).
- Pass tests for attitudes to safety, and their relationship with technology (for instance they should find new technology interesting but not naively trust technology).
- Pass drug screening for opiates, cocaine, marijuana, phenocyclidine and amphetamines.
- Pass a criminal background check.

The Consortium suggest persons-in-charge should undergo training. This would include understanding control of vehicles including stopping distances, controlled acceleration and braking, controlling evasive manoeuvres, knowledge of environment and human behaviour in order to better anticipate problems, techniques to help maintain attention during automated running, and familiarity with the technology used in the vehicle. After training, the trainee should have to pass a written, as well as driving, test. The trainee should receive training on conducting vehicle protocols before and after the vehicles' running. After being tested in an enclosed area, there would be supervised running on public roads. Initial trials should be conducted with two people on board. These should be able to communicate clearly and immediately with each other.

DfT's (2019) code of practice requires that there should be ongoing continuous development and training. SAE mobilus (2019) stipulate that in a scenario trialling automated vehicles, persons-in-charge should be monitored subsequent to passing the initial tests and commencing the trialling. This could include monitoring driving, self-reporting of incidents, updated tests of driving and knowledge of automated systems and drug testing (what automation exists would not excuse a person-in-charge of being under the influence of drugs or alcohol whilst operating the vehicle (Law Commission and Scottish Law Commission, 2018). Remedial testing could address any degradation of skills. It has also been suggested that for on-road trials, drivers' attention state should be monitored using gaze tracking and monitoring of hand position.

There may be substantial differences between testing and managing persons-in-charge during research trials compared to commercial service situations. One difference would be that commercial service shifts may be longer than trial shifts. Real services may also last longer (i.e., in months and years) than trials. For this reason, frequent refresher driver training may be necessary for persons-in-charge of real services, if the automation renders the driving task easy (Young & Stanton, 2007). Another difference could be that test drivers should expect frequent failures in automation during tests of automated vehicles (SAE, Mobilus, 2019). Hopefully, vehicles that pass testing stages and enter real-world service will function better and need human takeover less often for vehicular systems reasons than those used in trials. Logically this may mean longer periods of automated running, with the accompanying attention challenges, for real service personnel compared to trial personnel.

3) What challenges do non-automated bus drivers face (attention, fatigue etc) and how are these drivers recruited and tested?

Challenges faced by drivers of non-automated bus

Evidence suggests there is a range of aptitudes necessary for driving traditional, non-automated buses. As automated vehicle safety operatives will need to perform some of the tasks performed by traditional bus drivers, these aptitudes may be relevant when testing candidates for suitability. The aptitudes include spatial awareness, good customer service particularly including friendliness (Prioni & Hensher, 2001), ability to maintain concentration in what is a responsible role, ability to handle conflicting demands amidst distraction (Salmon, Young, & Regan, 2011), and ability to drive smoothly (particularly with regards to braking) so avoiding any unnecessary alarm for passengers (Prioni & Hensher, 2001).

Jacobs et al. (1996, p.204) suggest that one summary of the requirements of a traditional bus driver is to 'Be there, be safe and be courteous'. 'Being there' can be objectively gauged by absentee records, and 'being safe' can be measured by previous collisions. (Additional data could be drawn from the record of previous 'red flags' in driver performance monitoring system). In an Indian study, prevalence of bus drivers' previous crashes was found to be associated with acute levels of sensation seeking, as measured with a sensation seeking scale (Verma et al., 2017). Drivers with high levels of sensation seeking were found likely to engage in unsafe driving behaviour to achieve optimal arousal. For a number of overlapping scales, extreme scores, both very high and very low, were associated with crashes. For example, both extremes of susceptibility to boredom were found to be associated with road crashes: at one extreme, drivers may fall asleep while driving or lose attention. At the other extreme, risky experience seeking behaviour may be pursued. Similarly, both very high and very low scores on disinhibition and experience-seeking scales were associated with crashes. Risk-taking and sensation-seeking behaviour can be measured by the RT-18 scale (de Hain et al. 2011). Note that, in relation to automation, dangerous results of automation can include behavioural adaptation in which performance advantages achieved through automation lead to riskier driving behaviour (higher speeds etc.) due to risk homeostasis (Saffarian et al. 2012).

Level of courteousness may be hard to quantify objectively. Jacobs et al. also applied psychological scales to measure these qualities: They assessed hazardous thought patterns with four psychological scales, two scales assessed attitudes to safety and accidents, and the degree to which drivers assumed responsibility for accidents and safety, a life events questionnaire assessed past life experience, a cognitive ability test assessed verbal communication, prioritisation etc., and the Hogan Personality Inventory (HPI) assessed the 'Big Five' personality constructs. The 'conscientiousness' measure within the 'Big Five' personality test is also particularly useful for assessing whether an individual's personality is well suited to general bus operation. The 'neuroticism' measure within the same test may, by indicating a limited capacity to cope with stressful conditions, also be relevant. Short forms of the 'Big five' test include the NEO Personality Inventory (Costa and McCrae, 1992).

Bus drivers' performance, in terms of fuel consumption, vehicle longevity, safety and passenger comfort, can be monitored and assessed with platforms providing online information about driving characteristics and video monitoring of cabs (GreenRoad, 2020). Using this system FirstGroup report a fall in dangerous driver manoeuvres of 70%, and Stagecoach report are making the necessary progress towards its target of reducing fuel consumption by 4%. Technology such as the GreenRoad platform would be useful in the ongoing monitoring, and possibly in the assessment, of persons in charge.

Hardiness is an important quality for drivers of non-automated buses to possess. Hardiness is a characteristic by which an individual enjoys rather than fears challenge, low levels of which have been found to predict ill health in bus drivers (Bartone, 1989, cited in Tse et al., 2006). The challenges of driving non-automated buses for health and wellbeing include cardiovascular conditions, gastro-intestinal conditions, musculo-skeletal problems, depression, anxiety, post-traumatic stress, and vulnerability to substance abuse (Tse et al., 2006, p.89). Aspects of the job that can cause stress include poor ergonomics of cabins, shift patterns, traffic conditions (particularly under time pressure, which may or may not be a factor with automated buses) and violent passengers. The job demand-control model (Karasek & Theorell, 1990, cited by Tse et al., 2006) suggests that stress will develop where job demand is high but ability to make decisions is restricted. Tse et al. (2006, p.100) suggest that understanding locus of control (whether it is perceived as being within the individual or is external) may be important in training drivers, as it has been found to mediate 'between stress and well-being.' Due to the potential stress of driving non-automated buses, 'realistic job previews' should be offered to candidates (ibid. 2006) Protecting driver well-being will be in the interests of bus operating companies.

Fatigue is a specific challenge to bus drivers' well-being, which has recently been researched in the context of London, UK (Filtness et al., 2019). Previous to this report there was a lack of evidence on the subject. The research found 21% of surveyed drivers (n=1353) reported having to overcome sleepiness at least two to three times per week, and 17% had fallen asleep whilst driving during the last twelve months. Multiple factors were found to lead to driver fatigue, including navigating congestion and shift patterns that can include long, night-time and rotating shifts. Insufficient good quality sleep can thus be a factor, along with general health, stress and overwhelming mental tasks whilst driving. The context of the study (examining drivers in London, UK) may, however, not be representative of the rest of the UK, firstly due to a greater physical separation between driver and passenger, and secondly in drivers typically having to commute longer distances to their shift, exacerbating pressure on time for sleep. Measures used to assess the challenges faced by drivers of non-automated buses included measuring stress with the Stockholm Stress Scale and measuring heart rate variability. Sleepiness has been assessed with the Karolinska Sleepiness Scale (KSS) and measurement of long blinks. The study also measured the driving characteristics of speed and acceleration/deceleration intensity, in relation to driver fatigue.

Potential solutions for the prevalence of fatigue in non-automated London bus services may be helpful in an automated service. They include providing advice about sleep management (to all personnel), the provision of good places to eat and rest, well-maintained vehicles, an organisational culture which facilitates discussion around fatigue and measures to maintain and monitor physical health.

Non-automated bus, application and training processes.

Online information for potential applicants to become drivers for two bus operating companies were reviewed (Stagecoach, 2020, First group, 2020) and is displayed in Table 1. Note that the information is that given on the general website. As there may be details of more stages given to applicants, the absence of a 'yes' does not imply a 'no'. Table 1 suggests that both companies use processes that include a range of background checks, an initial assessment, a roughly three-week period of intensive training, and a period of driving commercial routes, with a mentor. This would seem an appropriate overall structure for persons-in-charge.

Table 1: Showing components of application and training process that are mentioned on application websites.

	First Group	**Stage Coach**
Application	Yes.	
Online test	Yes. Around 20 minutes. May cover 'customer service, verbal/numeric skills, ability to concentrate'*	
Assessment day	Yes. Applicant should bring driving licence, and 'driving licence summary from DVLA.'* Also includes practical driving test, basic numeric and verbal skills, questions on highway code, and an interview.	Yes.
DBS check	Yes.	
Medical	Yes.	Yes. Pre-employment medical in order to obtain Category D on driving licence
Main training	Yes. Around three weeks.	Yes – including induction, Classroom based assessments on: Theory test and hazard perception, case studies. Then tests on knowledge about vehicles and PCV driving test.
Post test		Another week including class work. Includes further driving training, learning about ticket machines. Different types of bus are driven.
Time with Mentor.	Yes, after three-week training trainee starts route learning with a 'buddy driver' *	Trainee covers shifts alongside a mentor for around two weeks.
First few months		For first months, driver will drive on limited number of routes only

*First Bus (2020) **Stagecoach (2020).

Standards and tests applied in the recruitment of train drivers may also be relevant to recruiting automated bus persons-in-charge[3]. A wide range of abilities are necessary in train drivers. Such abilities involve driving skills, including being able to adjust and react according to events, ability to anticipate and respond to problems, applying breaks, understanding all vehicular controls and indicators, and comprehending how the vehicle works, in order to report anomalies (Legislation.gov.uk, 2020). (Similarly, airline pilots must be able to understand the ways automated systems work in order to monitor them appropriately (Billings, 1991, cited in Orlady, 2010). Orlady notes that in the case of airline pilots increased levels of automation increases rather than decreases requirements for pilot training.) The train driver should also be able to react to factors external to the train including taking note of speed limits, having thorough knowledge of lines and installations on a route, and adjusting running according to timetables (Legislation.gov.uk, 2020). He or she should have interpersonal abilities including communication and leadership, (Railway operators, 2019). Necessary wider cognitive abilities include understanding and retention of information, the ability to understand the job's requirements (Legislation.gov.uk, 2020), and skills in compliance and legislation (Railway operators, 2019). The train driver should be responsible in relation to safety, security and unexpected situations. This may include degraded situations (in which a train develops a fault of failure (Railway operators, 2019), calling for assistance when there is an accident, and deciding where to stop the train in case of a fire (Legislation.gov.uk, 2020).

A website, created by a train driver and teacher of other drivers, (Traindriver.Org, 2020) suggests candidates for a train driver role will undergo a written application process, psychometric testing, psychomotor skills tests, manager interview, structured interview, and medical. Each stage eliminates candidates, with the tests being ordered for efficiency so that the maximum number of applicants fail as soon as possible. Aptitudes and psychometric means of testing used in the recruitment of train drivers have been incorporate in Table 3 at the end of this document. Results from psychometric tests are considered valid for five years, barring a major life event causing changed cognitive ability or behavioural nature. Railways employers may put structures in place to track such events. Changes in the driver's role can also affect the relevance of passed psychometric tests. Personnel administering the psychometric tests should have appropriate expertise in administering, interviewing, and interpreting results (RSSB, 2015), and hold the 'Test user: Occupational ability' qualification from the British Psychological society (p.8), and a certificate from RSSB for competence in delivering the tests that they publish. Railway employers should arrange audits of their psychometric assessment procedures.

Regulations for train driver licenses state that before and (periodically) after appointment train drivers must have medical examinations, which include a general examination, testing of sensory functions, testing blood or urine for diabetes, an 'ECG at rest', tests for illicit drugs and excessive alcohol intake, tests of cognition and tests of reaction time and hand coordination (Legislation.gov.uk, 2020). A driver must not, have a medical condition or medication that may compromise consciousness, attention, concentration, physical and mental capacity, balance, coordination, or sufficient mobility. There are also requirements for occupational psychological examinations and requirements laid out for hearing, ability to speak and vision.

[3] It should be noted that given the attractiveness of this job for many, on average 300 applicants are rejected in relation to one position (Jobtestprep, 2020). In addition to the seriousness of the safety implications of the role, this may make train driver recruitment particularly stringent.

4) What part can simulation play in assessment? What differences are there between simulated assessment and real life

Simulations have been used in many research studies including (Gold et al., 2018, Morgan et al., 2018, Ebnali et al., 2019, Young & Stanton, 2007). The evidence relating to automated vehicles to date has often been gathered from simulations (Waard et al., 2010, Morgan et al., 2018, Merat et al., 2014,), although with some drawing on experience from real vehicles (Flower et al.). In a research concept, simulations can yield a variety of information about participants. For example, Sarter et al. (2007), gained three types of data from a simulated aircraft. Firstly, they gathered behavioural data on how the participant handled the simulation tasks. Secondly, when the simulation finished, participants were probed about their mental model of what the automation had been doing. Thirdly, eye-tracking data (through tracking both the head and gaze of the participant) registered the duration for which a participant looks in a specific direction. Durations can be classified as glance, gaze or stare (Kilingaru et al., 2013) with information only being perceived when a gaze is a minimum of 200-600ms (Arnold and Tinker, 1939, cited in Kilingaru et al., 2013). Eye-tracking has also been used to compare eye movements between expert and novice pilots, with the former being used to provide a baseline. To assess appropriate gaze patterns during simulation, eye tracking is able to indicate how long a specific instrument or area is *not* looked at (Kilingaru et al. 2013). Eye and head tracking has also been used in the context of a simulated road vehicle by Merat et al. (2014).

Simulations have also been used to induce and measure different types of fatigue (Saxby et al., 2013), which may, as discussed, be a significant challenge for a person-in-charge. Saxby et al. induced active fatigue by gusts of 'wind' making the simulated vehicle veer requiring correction to course. Passive fatigue was induced by the simulated vehicle being fully automated and requiring the participant only to monitor the vehicle. It was found that thirty minutes was sufficient to induce changed states in the participants. The experiment suggested that subjective scales may pick up increasing passive fatigue even before actual performance deterioration occurs (i.e., subjective unease is a warning sign of ensuing performance issues.) Overall capacity for attention has also been measured using simulations, through the incorporation of secondary tasks. For instance, driving tasks have been combined with a simultaneous task assessing whether rotated shapes were identical or not (Young & Stanton, 2007).

Besides research uses, simulation may be used for training persons-in-charge of automated vehicles. Simulation's potential in this respect was compared to video training (by Ebnali et al., 2019) with results indicating the simulation out-performed the video training. The study suggested simulations may alter, as well as assess performance: The level of participant trust towards automated cars was shifted towards more moderate levels, by both simulator and video-based training.

Strengths of using simulations include participants generally taking simulated driving tasks seriously, despite the situation being simulated only (Saxby et al. 2013). In addition, after testing twenty-five professional bus drivers, Brookhuis & Waard de (2006) concluded that in order to qualify for semi-automated vehicles, simulated elements should be used to test applicant persons-in-charge. The element should be mandatory and type-approved, as is the case with aviation. Using simulators for training has been noted in the context of train drivers to offer the ability to simulate occurrences that may be infrequent in actual vehicular running (RailEngineer, 2017). Weaknesses of simulations include that they do not pick up the effects of circadian rhythms on fatigue unless these are accounted for in the design of the tests (Saxby et al., 2013). Additionally, in relation to arousing fatigue, simulations may be simplified representations of the changing conditions of real life driving (Saxby et al., 2013). Intuitively. The relative short duration of simulations may also weaken the resemblance to real driving tasks.

Conclusion

Table 2, showing the aptitudes necessary in a person-in-charge was originally compiled in a preliminary, two-day, draft of this document. The fact that only minor additions have been made to the table on the basis of this more extensive review is instructive. It might suggest a 'bottoming out' of the aptitudes that previous academic evidence would suggest as relevant. It may be however, that in the course of real recruitment, testing and training of persons-in-charge, new necessary aptitudes are uncovered.

Table 2: Attributes necessary to being a safety operative

Attribute necessary for human driving	**Implications/relevance under future automation**
Spatial, and Situational, awareness	Will depend on nature of automation and manual mode, i.e., will the vehicle be steerable by manual means?
Ability to drive smoothly	Will depend on nature of automation and manual mode, i.e., will braking be applied manually in some situations?
Ability to drive safely	Will depend on nature of automation and manual mode. Possibly will require both a licence and a period of experience driving the relevant class of vehicle.
Customer service (particularly including friendliness	Still relevant. The level of challenge with this may depend on whether automated operation is more, or less, taxing than traditional driving.
Maintenance of concentration	Very relevant. Likely to be a more 'passive' concentration, i.e., monitoring the automated systems and running, rather than steering and so on. Can be challenging, fatiguing and stress-inducing in automated running: particularly if the driver is left: 'out of the loop' for the duration.
Ability to handle conflicting demands amidst distraction	Likely to still be relevant, but different, to traditional driving.
Low level of neuroticism, necessary to cope with stress and conflicting demands.	Will depend on whether automated running is more or less stressful than traditional driving.
Reliable attendance for shifts	Still relevant.
Level of conscientiousness, including not being under influence of drugs or alcohol	Still relevant. In particular unconscientious persons-in-charge might be tempted to engage activities other than supervising the vehicle, during their shift. A person-in-charge should have an accurate understanding of what they are responsible for, what their company is responsible for, and what the vehicle is responsible for.
No excessive sensation seeking tendencies. Neither extreme of susceptibility to boredom	Likely to still be relevant. A risk homeostasis reaction to the capability of automation could

	lead to the person-in-charge taking greater risks
Robustness against fatigue, including absence of medical conditions associated with fatigue or sleepiness?	Very relevant, particularly as monitoring tasks could be liable to fatigue.
	Elements necessary for automation that do not have precedent in traditional driving
	Ability to rapidly resume control in an emergency.
	Maintenance of driving skills if these are rarely used.
	Confidence in switching between automated and manual modes. Particular confidence in manual driving after automated running.
	Appropriate level of understanding of, and trust (neither excessive nor insufficient) in, automated systems.

An important question for bus operating companies will be whether drivers of non-automated buses are likely to make good persons-in-charge of automated buses. As Table 2 shows, there are many qualities needed to be a traditional bus driver that will still be necessary in bus drivers. However, the weighting of importance of these may change between the two roles. A specific and important change might be that for non-automated vehicles, the requirement for resilience against active fatigue (from mental overload) may shift to requiring resilience against passive fatigue. It does not by any means follow that an individual who is robust in over-stimulation, will be so in under-stimulation. The sense from the evidence is that this under-stimulation will be a significant challenge, one that should be carefully managed by operating companies. Table 2 also suggests that a new range of capabilities will be required in the person-in-charge that are not at all needed in the traditional driver, including for instance an accurate conception of automation's capabilities and an appropriate level of trust in these. Thus, overall, it is very questionable that the best performing drivers of non-automated buses will also be the best with automated vehicles. However, this document has not definitively answered this question.

Best practice, codes of practice, and training programs are emerging for automated vehicles, but these tend to focus on trial situations rather than commercial services and do not address buses specifically. Little academic evidence was reviewed that exactly addressed drivers of automated buses, suggesting a present gap in knowledge. The search for evidence was not exhaustive and there may, in particular, be more evidence around what strategies can be used to keep persons-in-charge in the loop and also how ongoing monitoring of persons-in-charge once appointed should be managed. This monitoring may be informed by the processes used by bus operating companies, of monitoring drivers of non-automated buses.

The evidence gathered on simulation suggests it can have a useful role in selecting, training, and monitoring potential persons-in-charge as well as achieving research goals. It may be that some of these processes could be achieved simultaneously. The evidence from extant processes for recruiting drivers of non-automated buses suggests however, that whatever training is given by simulation will need to be followed by a period of real-vehicle training, with the presence of a 'buddy'.

Table 3 summarises a list of psychological tests and scales that may be useful in assessing aptitude for operating automated buses. Please note that some of these have been generated by the University of the West of England and so should not be used without appropriate attribution/recognition of their source. If in doubt please contact, in the first instance, Graham.Parkhurst@uwe.ac.uk. Other of the tests, marked with two stars, are used to test train drivers.

Table 3: Psychological tests and scales

Test or scale	Description	Relevant Reference
NASA-TLX	Assesses perceived workload, in order to evaluate a task or team's performance	Hart (2006)
Trust in automation state checklist	Measures trust in automation, including dependability and reliability.	Jian et al. (2000)
Trust in Automation (TiA)	Measures trust in automation in five areas: Reliability/Competence, Familiarity, Trust, Understanding, and Intention of Developers.	Korber (2018)
Situation Awareness Rating Technique (SART)	A self-evaluation of situational awareness.	Selcon and Taylor, (1990)
Situational Judgement Exercise (SJE) and MMI	Tests for behavioural aptitudes and 'occupational psychological deficiencies, particularly in operational aptitudes or any relevant personality factor.'	
Paper Group Bourdon and Test of Everyday AttentionOccupational (TEA-Occ)**	Selective attention - The ability to differentiate between different sources of information and attend selectively to them, for example distinguishing and attending to alarms (selective attention). Divided attention - The ability to switch attention between sources of information, for example lineside information and in-cab information and perform different tasks in parallel, for example making train announcements while on the move	

WAFV Vigilance** Test	Tests 'the ability to attend and respond to stimuli which occur relatively infrequently and over extended periods of time.'	
TRP1 Trainability** for Rules and Procedures Test (part 1)	Memory. 'The ability to learn, recall and apply job related information in appropriate time limits, for example learn new information in training; remembering instructions from signallers; applying specific rules and procedures.'	
TRP2 Trainability for Rules and Procedures test (part 2) **	Problem solving and decision making 'for example fault diagnosis; understanding and interpreting information from instrumentation.'	
ATAVT Adaptive Tachistoscopic Traffic Test **	'The ability to anticipate elements in a traffic environment and make a correct decision about how to respond given the speed and distances involved, for example identifying a landmark cue before a station and starting to decelerate.'	
WAFV ATAVT **	Reaction time. Tests 'a quick and adequate response to simple and complex visual and acoustic stimuli and the associated quality of performance.'	
2HAND Two hand coordination test**	Tests 'the ability to make appropriate and controlled movements in response to decisions about complex stimuli.'	
Multi-Modal Interview (MMI)* Optional: Written Communication Test. **	Tests 'The ability to read, listen, understand and respond appropriately, and effectively convey information orally and in writing.'	
System usability scale (SUS)	A quick method for assessing how easy individuals find the use of industrial systems.	Brooke (1996)

NEO Personality Inventory	A short version of the 'big five' personality test	Costa and McCrae (1992)
Hogan personality inventory	Related to the 'big five' model of personality	Jacobs et al. (1996)
RT-18	A short scale assessing risk-taking and sensation-seeking behaviour.	De Haan et al. (2011)
Zuckerman's sensation seeking scale	Includes assessment of Thrill and adventure seeking, Disinhibition, Experience seeking and Boredom susceptibility	Verma et al. (2017)

* This test assesses oral rather than written communication.

** Tests used for train drivers. Information taken from RSSB (2015 p.14 and 15) Train driver tests can also include a 'Safe concentration & attention test' to evaluate candidates' ability to combine multiple tasks: analysing shapes, and simultaneously responding to prompts to press a right or left foot pedal (Traindriver.org, 2020). There may also be fault finding tests, assessing ability to correct faults whilst remaining calm (Jobtestprep, 2020).

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