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of Connected & Autonomous vehicles

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[D5.1] – Requirements and competence models for CAV relevant training situations

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[D5.1] – Requirements and competence models for CAV relevant training situations			
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List of acronyms	
Acronym	**Meaning**
ACI	Automobile Club d’Italia (IT)
CAV	Connected and Autonomous Vehicles
EBU	European Blind Union
GPS	Global Positioning System
HMI	Human-Machine Interface
HSS	Home Study Simulator
ITL	In the Loop
L3/L4/L5	Level 3/4/5 (for driving automation)
LIST	Luxembourg Institute of Technology (LU)
NDRT	Non-driving-Related-Task
OB	Objective
OTL	On the Loop
OOTL	Out of the Loop

PC	Personal Computer
RDS	Rds Driving Services Limited (UK)
SA	Situation Awareness
SAE	Society of Automotive Engineers
TOR	Take over request
UBFC	Université Bourgogne - Franche-Comté (FR)
WP	Work package

Notice

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Executive summary

The PAsCAL project funded under the "Horizon 2020" Research and Innovation program aims to improve the understanding of the implications of connected and automated vehicles (CAVs) on society. The project will create a "Guide2Autonomy" to capture this new knowledge. Outcomes from the project will contribute to the training of future drivers and passengers and will help decision-makers to move towards the new forms of individual and collective mobility made possible by the spread of driverless cars.

To fulfil these purposes, specific surveys have been prepared in WP3 and behavioural analyses are carried out in WP4 with using modern technologies, such as driving simulators and virtual reality platforms. WP5 will bring elements on how best to train CAV users (the current "drivers"), as well as the necessary certifications that must be obtained and any new traffic rules to be adopted.

In addition, PAsCAL will finally create, in WP6, five road-transport pilot projects, conducted in different countries of the European Union. One of these will specifically try to verify the results of WP5.
All the collected data will be then analysed in WP7 in terms of impacts and KPI.
All this new knowledge will be incorporated in WP8 into the "Guide2Autonomy", which will be available to all relevant stakeholders.

In all this context, the current document aims to present the requirements and competence and cognitive/affective models for CAV relevant training situations.

The whole document is broken down in 6 sections.

Following the Introduction section, section 2 presents the requirements of a CAV environment in which the takeover phase and driver behaviour are key. These requirements propose several ways and variables to investigate facilitators or barriers of a safe takeover, such as autonomy levels, driver factors and two types of road educational environment (an urban scenario and a highway scenario).

Then, section 3 details the competence and cognitive models of Home Study Simulator drivers dealing with several conditions.

To perform an efficient and timely takeover, the models enlisted in Section 3 detail the knowledge and skills related to the CAV, the Situation Awareness a driver has to demonstrate before, during and after a takeover, including the cognitive, affective and emotional resources regulation at every moment.

The document ends with a concluding section followed by related scientific references and a series of annexes.

Both cognitive and competence models will be inputs to develop the road education modules for drivers and trainers in a CAV environment that will be described in D5.2 and D5.3.

1 Introduction

1.1 Purpose and organization of the document

In line with tasks 5.1 and 5.3, this document details, on the one hand, the requirements of a CAV environment with specific reference to a road educational environment and, on the other hand, the cognitive and competence models of trainers, professionals and learner drivers. These elements will serve as inputs to develop the road education modules for drivers and trainers in a CAV environment foreseen in Tasks 5.4, 5.5 and 5.6.

Following the Introduction (section 1), the document is broken down into two main sections

In section 2, we present the requirements of a CAV training environment regarding the specific main features considered relevant to WP5 purposes: autonomy level, driver type, driving mode and two types of road educational environment: an urban scenario and a highway scenario. Each scenario confronts the drivers with several types of features and situations (intersections, signs, road users, incidents, etc.). If both scenarios share common elements, regardless of the field country (Italy or the UK), few elements will differ (signage, some rules, etc.).
Each environment will be tested through L3 and L4 CAV.

Section 3 details the competence and cognitive models of CAV drivers dealing with several aforementioned conditions.

The document ends with a concluding section (Section 4) followed by related references and a series of annexes.

1.2 Intended audience of this document

The audience for this document is (1) the consortium members of the PAsCAL project and (2) researchers and all stakeholders with interest in CAV skills and development, and (3) the European Commission.

1.3 Challenges encountered

HSS development

As one of the objectives of the PAsCAL project is to investigate new CAV training needs, one intermediary step is the definition of the related CAV environment, the linked competences and cognitive components necessary to perform the driving tasks, tested through the Home Study Simulator (HSS).

The LIST's Home Study Simulator was selected among the many simulators available in the PAsCAL project because it is a lightweight simulator, allowing flexibility in terms of experimentation location. Initially planned to be used at subjects' home and moved easily from place to place. Therefore, for the purposes of WP5, it was the ideal simulator to be used at ACI and RDS driving school premises. However, as previously developed by LIST and made available to the project, the software proved unable to meet the needs of the driving school partners ACI and RDS. Hence, a new version had to be developed practically from scratch.

The purpose of using a driving simulator in driving schools and in Research/Universities is different, thus affecting its characteristics.
The use of driving simulators in driving schools as a training tool is still debated. It is a useful tool to allow novice drivers to practice in a safe way how to handle the vehicle (steering wheels, pedals etc.) and complex situations drivers may encounter on roads. However, the complexity of its development and update and its costs make the trade off a challenge. In fact, a driving simulator for the purposes of driving training is targeted at learner drivers and/or professional drivers' updates. Hence, it must have specific features meeting these targets' needs. The most important feature is realism. The simulator has to reproduce as faithfully as possible the physics of the vehicle and its behaviour in the different conditions proposed as well as the road environment and all traffic situations in the most realistic possible way, for trainees to effectively "experience" the

dangers of the road and how to react to them, without feeling like in a videogame.
Moreover, the simulator must be able to reproduce different environments and, randomly, all possible dangerous situations. This makes the development of a driving simulator extremely complex and completely different from "driving simulators" as developed for the purposes of research. The latter in fact, usually has to concentrate on one or some specific variables which is/are the object of study. Consequently, the required realism is limited to those specific variables and simulations do not require such a wide array of situations and complexities.

Moreover, in the case of WP5 and HSS, complexity was increased by considering different levels of automation (L3 and L4) whose features and characteristics are not yet fully detailed, neither in the scientific community nor by industry. In this case, the challenge for LIST as a technical developer of the HSS and for ACI and RDS as driving training experts, was to agree on designing compromise solutions that would allow answering the questions posed by training even in circumstances of relative uncertainty of the behaviour of the L3/L4 vehicle in critical situations. This proved to be a very long and complicated task, compelling tests to start mid July 2021.

HSS experiment with Covid-19 constraints

As mentioned during the review meeting last January 2021, some PAsCAL activities suffered from the COVID-19 pandemic situation imposing social distancing and preventing face-to-face meetings. For a long period, the partners had to organise themselves for working exclusively remotely. In this context, tasks related to the design, development and setting up the simulator have been considerably delayed because these complex tasks to adapt the HSS to answer new training requirements imply usually continuous and intensive interactions between partners. Moreover, the experiments need the subject to come to the partners' respective facilities, which has been forbidden/made much more complicated for many months, depending on the sanitary rules of each country. It also implied heavy additions to the experimental protocols to ensure both subjects' and experimenters' safety while running the experiments.

Several readjustments to the planning of these tasks were made in the initial 36 months, but the duration of the sanitary crisis was forcing us to

the necessity to extend the project by six months (agreed in the third amendment) to carry out these tasks and have the necessary time to analyse in WP7 the collected data as well as to produce all the recommendations for the Guide2Autonomy in WP8.
Let’s also underline that Covid-19 was also a major changer regarding people’s mindset/attitudes. Most European citizens haven’t been allowed to travel for months and, even if they are now allowed again to travel and meet face-to-face, we still observe some obstacles in recruiting people due to outbursts of caution and reluctance to participate massively in the experiments.

To mitigate the lack of tests’ subjects (due to HSS development delays and Covid-19 constraints), competence and cognitive models have been built first thanks to literature review and then thanks to available HSS test feedbacks. The validity and generalizability of the models have room for improvement. Indeed, even if we consider that the models designed have high probability to be confirmed with more data, it is worth noting that 1. our models will be enriched with the ongoing tests and 2. the more empirical data we consider, the less risk we have to define inaccurate models.

2 Requirements of a CAV environment with reference to two types of road educational environment

One of the main goals of PAsCAL is to investigate new “drivers" training needs and certification requirements for new technologies and different levels of automation. To reach this goal, WP5 needs to understand how CAV users perceive and treat situations in a CAV environment and develop and pre-test training solutions to enhance drivers’ behaviour in different scenarios. To do so in an effective way, it is necessary to consider the actual situation.

There are currently no standard European road rules or rules specifically dedicated to driving education and training. The SIMUSAFE project recently draws a European Map of Training Modules (Picardi et al., 2019), which highlighted the considerable fragmentation of the sector. The most advanced and cutting-edge driving schools’ networks in Europe adopt fairly similar methods, meeting the national regulations on requirements to obtain the driving licence but adding technical-practical modules dedicated to specific topics useful to license “safe drivers” such as eco and defensive driving, use of L2 Advanced Driver-Assistance Systems and/or refreshment safe driving courses. Hence, driver education and training for higher levels (3 and 4) of autonomy is virtually unknown terrain.

Vehicles with higher levels of automation are not yet on the roads, and very few people have had the opportunity to actually experiment or use in practice these vehicles. Moreover, there are no shared specifications or standards for their development and implementation.

The progressive deployment of these vehicles on the roads will have to consider the need to interact with the simultaneous presence of traditional vehicles and the need for regulatory adjustments capable of regulating this new situation.

Higher levels of autonomy will allow drivers to shift their attention from driving to other tasks, thus shifting responsibility from the human driver to the autonomous vehicle. When this shift may happen, which dangers it entails and how it should be handled, needs to be explored and solved.

For WP5 purposes, three goals were to be achieved:

- To assess the level of acceptance of autonomous driving systems by experienced and learner drivers.
- To test drivers' reactions in all situations requiring the driver to regain control of the vehicle.
- To develop the guidelines for teaching, to disseminate, and to raise awareness among users during the different stages of technology deployment.

To reach these goals, ACI and RDS, the two driving schools' partners in PAsCAL, used as a reference and starting point of the research the national driving training programmes of their countries, respectively Italy and the United Kingdom, and their specific modules dedicated to advanced systems training.

Based on their experience and the principle of best-practice approach, the driving schools selected the features that may affect driving behaviours as well as CAV acceptance, thus influencing the driving education and training solutions to be developed. These features will be considered for testing and most of them had to be reproduced by the HSS to allow the analysis of the behaviours and reactions of drivers in critical situations, thus deriving useful information for the development of a dedicated training methodology.

The features which driving schools selected as relevant are Automation levels, Driver factors and Road Environments.

2.1 Automation levels

The Automation levels considered for driving training purposes are Levels 3 and 4 in line with the Society of Automotive Engineers specifications. Differently to L5, in fact, these two levels still require the presence of a driver, hence driving training is required.

L3 and L4 vehicles will be able to perform autonomously many/most of the tasks normally performed by drivers. But not all. The parameters of driver's intervention when the vehicle is unable to perform autonomously the driving task, need to be explored and specified in detail, the ways and methods of intervention must be evaluated and itemized according to the different situations that occur on the road, with a view to ensure the safety of every road user.

Moreover, since there will be an indefinitely long period of time during which L3/L4 vehicles will have to share the road with traditional and lower levels vehicles, the interactions between vehicles with different performances need also to be considered and evaluated, with a view to ensure the predictability of the behaviour of each vehicle/driver. Therefore, the HSS was requested to simulate the behaviour of L3 and L4 vehicles. These levels have been and will be used for tests with different samples of testers in driving schools and at LIST.

2.2 Driver factors

As the driver is one of the key factors that inevitably influence road safety, at least up to full and complete automation, three driver factors will be taken into consideration to develop a driving training methodology dedicated to CAVs: experience, driving attitude/style and acceptance.

Considering driving experience, three types of drivers are considered:

- Novice/learner drivers: persons who are learning the rules of behaviour on the road and how to manage the vehicle.
- Experienced drivers: persons having obtained their driving license since at least 2 years, who have had time to experience various driving situations on road and to acquire mechanical and behavioural driving skills.
- Professional drivers: persons whose profession implies driving, i.e. taxi, bus, or truck drivers, who have extensive driving experience, know vehicle behaviours, and know how to handle correctly and efficiently the most varied situations on the roads. For this type of drivers, specific regulations provide in most cases for periodic training and refresher courses.

Tests in driving schools will be made using representatives of the three categories defined above, on the basic assumption that their driving abilities imply different needs, in terms of training and acceptance. Furthermore, this will allow to have an insight of the future needs related to road education, when the driving skills of drivers will probably decrease due to the increasing role of technology but, on the other hand, will be extremely necessary in case of failure of the technology.

Considering driving attitude/style, two driving styles which roughly encompass most driving styles and behaviours of drivers, are to be taken into account:

- Eco/safe: the driver tends to keep a predictable behaviour, a moderate and constant speed, avoids sudden accelerations and braking.
- Sport/aggressive: the driver privileges the “pleasure of driving”, speed and exploiting the vehicle potential, thus reduced stopping distance, speed in a bend, rapid acceleration, and deceleration.

These driving styles are related to the personality of each individual, though partly influenced also by experience. Driving schools asked this feature to be reproduced by the simulator in the autonomous driving mode, as it may influence the reactions of the driver as well as his/her acceptance of CAVs.

As another driver’s internal factor to consider, the driver expectations and close concepts (e.g. acceptance, trust) needs to be discussed.

As articulated in D3.1, there are several user expectations that might (not) be violated during a CAV experience. Specifically, D3.1 shows that people in general have mildly positive attitudes towards CAVs. Moreover, previous research shows that L5 acceptance is positively predicted from experience with lower level CAV features (L3). Thus, it is predicted that L3-training also translates into even higher acceptance of L4 CAV (as measured by WP3 measures).

As is evident from WP3 (see the D3.1), however, acceptance is a multi-facetted construct. Specifically, WP3 showed that acceptance depends on the expected consequences of using CAVs with regard to *efficiency*, *safety*, *privacy*, and *sustainability* as well as the *perceived ease of use*. It is plausible that those critical dimensions are affected by L3 training in different ways.

Obviously, successful L3-trainings will have a positive effect on the ease of use, which will in turn increase CAV acceptance. Likewise, training should lead to more positive expectation regarding the safety dimension. It is an open question, however, if L3 experience and training will lead to better or worse expectations regarding efficiency (since that factor comprises travel comfort which is likely to go up, but also travel speed which is likely to go down for many drivers). Other facets of L5-acceptance may be unaffected by training, though it is possible that the drivers use the

CAV experiences to draw inferences about data privacy or even sustainability.
After all, results from WP5 (published in the D5.2 and the D5.3) regarding acceptance will not only further the understanding as to whether experience and training increase acceptance, but using the WP3-measures, they will indicate why this is the case. At the same time, the results feed back to WP3, and show if the factor solutions presented in D3.1 are robust across levels of automaticity (L3-L5) and levels of experience.

2.3 Road environments

In addition to automation levels and driver factors, urban and highway environments account for most of the driving situations. Hence, they need a detailed description of their features and their use within the tests.

2.3.1 The urban environment

As a matter of fact, every day drivers face the complex urban environment with its multiple and stressful situations.
It is, therefore, necessary to consider the urban environment and its distinctive features: road intersections (crossroads and roundabouts), vertical/horizontal road signs, traffic lights, pedestrian crossings, public transport stops, traffic volumes and types of road users.
As to the experienced driver, the study will assess their level of acceptance of autonomous driving systems. In particular, during the L3 CAV simulation, the driver should avoid interacting with the vehicle controls. Conversely, during L4 CAV simulation the tests will assess the ability of the driver to regain control of the vehicle, by analysing her/his ability to evaluate and react to a CAV system's request.

As to the learner driver, the urban environment is always the first and more complex situation in which to learn to drive. Differently from the experienced driver, in the L3 CAV simulation, the tests will focus on the driver's ability to promptly and correctly assess the circumstances in which it would be better/necessary to regain control of the vehicle. In L4 CAV simulation, the tests must evaluate the driver's ability to respond to the CAV's request to regain control of the vehicle as well as her/his ability to correctly interact with the vehicle controls to continue a safe journey.

In order to find points in common with the national driving training programmes and in view of developing a teaching methodology able to explain and disseminate a CAV culture, it is advisable that the urban environment set for the simulator includes the following features, which – for convenience – we describe below using the graphic currently adopted in national driving license theory tests.

2.3.2Intersections

Different types of urban road intersections to test drivers' ability to interact with the different levels of CAV. Suggested types from the two countries were provided to LIST, to consider for the training environments, including diagrams to aid with this process (Figures 1).

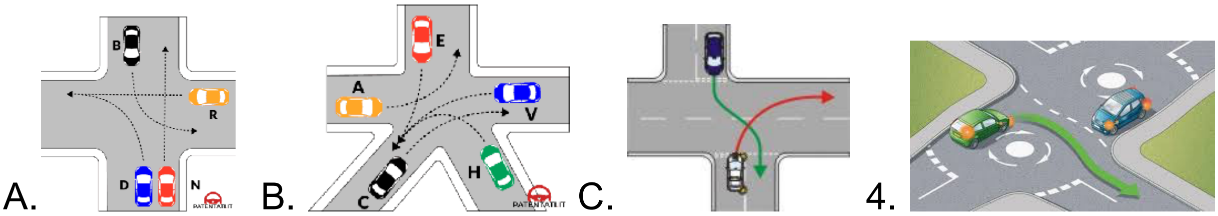

Figure 1. A. Italy 4-way crossroads B. Italy complex 5-way interchange
C. UK staggered crossroads D. UK double mini-roundabout.

The diagrams show different intersections within an urban environment along with arrows indicating which vehicle should proceed first accordingly to the rules. It is necessary for drivers to understand how to respond when dealing with all different junction types.

Complex junction types will always create the most risk for drivers, and these are often then the focus of current driver training materials with methods to assist the new driver with how to tackle such junction types. We provide a ‘best practice’ technique new driver's use when considering their approach to any such junction in the future.
To better understand how this can be transferred within the new training materials going forward for use with learner drivers in a CAV environment, we needed to test such junction types within the HSS.
This same principle of ‘best practice’ approach applies to subsequent junction types, and therefore to fully design and plan for future training programs within a typical CAV environment, it becomes necessary to test each type within the HSS.

2.3.3 Roundabouts

Traffic flowing freely is an important part of why roundabouts are a common feature within an urban environment. To ensure we understand how drivers of CAV cope with interaction between CAV and non-CAV at these important junction types, it is necessary to include them in the HSS. Not all drivers of non-CAV can be relied upon to operate their vehicles within the road rules, and this could cause CAV operating in autonomous mode to struggle to keep up with traffic flow. This factor needs to be considered in the methodology of creating new training materials.

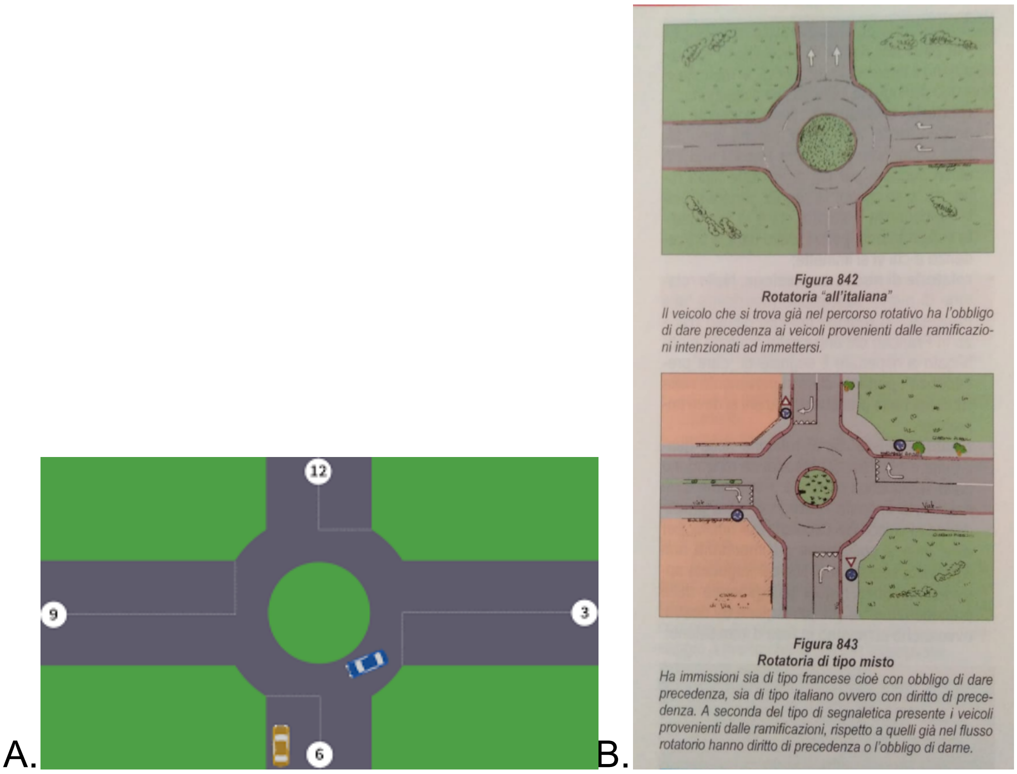

Figura 842
Rotatoria "all'italiana"
Il veicolo che si trova già nel percorso rotativo ha l'obbligo di dare precedenza ai veicoli provenienti dalle ramificazioni intenzionati ad immettersi.

Figura 843
Rotatoria di tipo misto
Ha immissioni sia di tipo francese cioè con obbligo di dare precedenza, sia di tipo italiano ovvero con diritto di precedenza. A seconda del tipo di segnaletica presente i veicoli provenienti dalle ramificazioni, rispetto a quelli già nel flusso rotatorio hanno diritto di precedenza o l'obbligo di darne.

Figure 2. A. UK roundabout B. Italy roundabout examples

2.3.4 Double-lane roundabout

Large multi lane roundabouts in urban areas especially, can create risk situations for all drivers, and are of particular worry to new drivers who often lack experience. To this end, being able to assess how drivers can interact with CAV levels of technology in such situations through the HSS enables trainers to test which 'best practice' approach techniques work best and should therefore form part of our training proposals for the future. An increased number of lanes and junctions on a given roundabout increase the potential number of conflicts and require greater concentration from the driver.

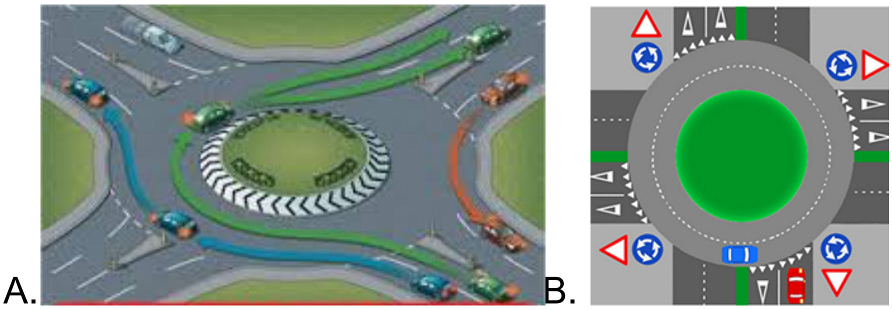

Figure 3. A. UK 2 lane roundabout B. Italy 2 lane roundabout.

2.3.5 Pedestrian crossings close to a bus stop area

Not common within the UK, this type of road feature within Italy can result in a high-risk road situation. Included within the HSS to better understand how drivers of CAV's would respond to this risk and enable trainers to consider 'best practice' approach routines for future training materials.

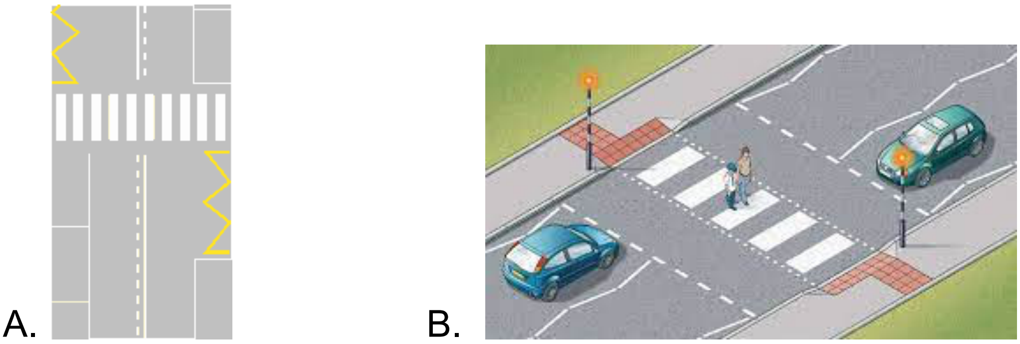

Figure 4. A. Italy bus stop adjacent to pedestrian crossing B. UK standard pedestrian crossing supplied for reference.

2.3.6 Pedestrian and cycle crossing

Again, considering the raised level of risk presented in these scenarios, it was necessary to include these within the HSS to assist trainers in the planning of future training materials.

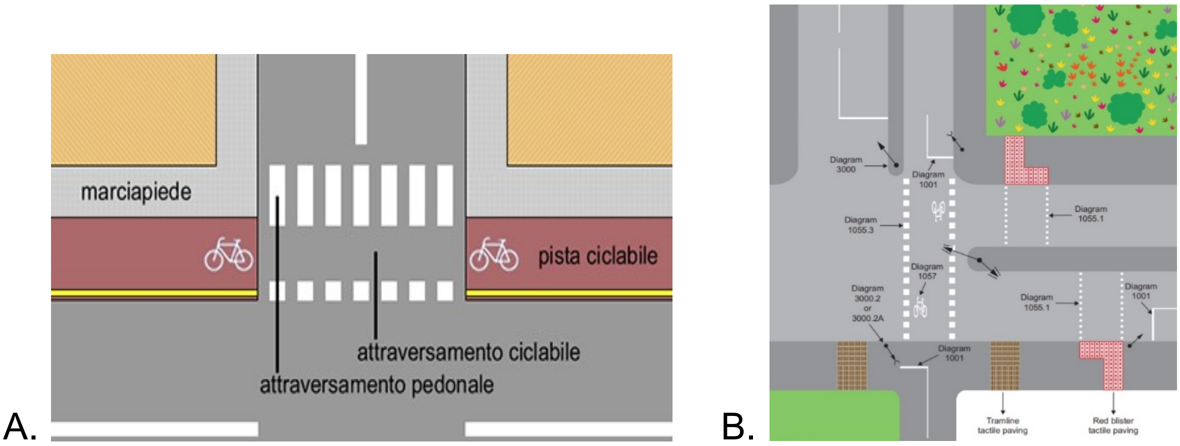

Figure 5 A. Italian version B. UK version.

2.3.7The Highway/motorway environment

(Note: Highway Road type (Italy) equate to Motorway Road type UK.)

The highway environment is essential for several reasons. First of all, due to the expected “safety” of this type of routes, it represents the very first application field for vehicles equipped with L3 CAV and L4 CAV technology, as well as another relevant test case for measuring the level of acceptance of CAV driving strategies.

In fact, throughout Europe there are already many examples of highways used as testbeds for autonomous vehicles and recently, first among all, the UK government has announced (April 28th 2021) that Level 3 automated vehicles will become legal on the nation’s roads later this year (Department for Transport, 2021).
The UK Department for Transport (2021) has also set out the parameters within which automatic lane-keeping systems (ALKS) must operate to allow a driver to legally take his attention from the road and perform a completely different, non-driving-related task while at the wheel – classed as Level 3 automation.
The proposed new UK law marks the first in many steps away from full driver responsibility – a driver will be legally allowed to completely take their attention from the road, so long as the ALKS can give the driver

adequate warning (around 10 seconds) of when they need to retake control. If they do not retake control the vehicle, it must automatically activate its hazard lights and gradually slow down until eventually it comes to a safe stop.

Initially the new law on ALKS will only apply at speeds of up to 37mph – it's primary use being foreseen as for moving slowly in jams on multi-lane highways – but there is an expectation that this speed limit will increase as the technology proves itself.

In response to this move by the UK government, which will surely be followed soon by other governments, it is essential that we consider the risks involved with the driver's ability to regain control when requested to do so by the CAV.

To achieve this, driving schools requested the HSS to provide an opportunity for trainers to review both CAV level 3 and level 4 over some distance of driving within a Highway environment.

Given the monotony and length of the tracks, at first drivers are likely to mostly rely on the automated driving, also in L3 CAVs. Then, though, if the vehicle uses a too "conservative" driving style, thus increasing the travel time, an experienced driver might get annoyed and decide to stop using the automated system.

Conversely, if the driving style is too "sport/aggressive" (reduced stopping distance, speed in a bend, too rapid acceleration and deceleration), it could trigger feelings of fear and insecurity in the driver, inducing her/him to regain control of the vehicle (L3 CAV) or reducing the level of acceptance of automation (L4 CAV).

For both driver types considered for evaluation, it is also important to measure their real ability to manage possible unexpected circumstances in which it is necessary to regain control of the vehicle. This measurement is essential due to a few factors, such as:

- the driver attention may be lower after several hours of automated driving (Strayer & Cooper, 2015), even if the highway track is safer;
- a higher driving speed causes an emotional reaction of the driver facing a dangerous situation and reduces the time available for the possible corrective manoeuvres.

These factors together decrease the Situation Awareness, leading to increased reaction time and safety hazard.

Similarly, to the urban scenario, in order to evaluate acceptance and, subsequently, to develop the CAV oriented teaching methodology, the simulation should reproduce the Highway/motorway scenario in the most realistic possible way, by inserting all the constituent elements required by regulations (compliant signage, side barriers, emergency lane, lay-bys, acceleration and deceleration lane).

By making the environment realistic, it is possible to evaluate how much the level of attention drops due to the "monotony" of a driving journey on highway, how much the driver trusts autonomous driving given the supposed lower risks of an accident and how fast and efficiently the tester is ready to resume controls after several minutes of autonomous driving.
To make the simulation more realistic, the simulation was to start and end at motorway entry/exit; the programmers opted for a service area by having the car enter the flow of traffic via the acceleration lane, which once explained to the testers, will have no relevance on the test's results.
The scenario foresees some pitfalls that can arise in reality; specifically, irregular traffic with the random presence of

- Lorries: which may cause sudden/unexpected slowdowns because of instinctive fear and unpredictability of behaviours.
- Accident: which may narrow the carriageway with/without lane change, presence of marked/unmarked obstruction.
- Tunnel: which requires speed reduction and higher levers of driver's trust in the vehicle's ability.
- Fog which limits visibility and requires higher levers of driver's trust in the vehicle's ability.
- Road construction sites with reduction of lanes. The initial idea, in this case, was a change of carriageway with two-way traffic (contraflow) as it represents a frequent situation on real roads and a potentially dangerous situation at which the driver should pay close attention at and, at the same time, trust the autonomous driving system. However, the complexity of implementation of such scenario in the HSS compelled the partners to compromise on a less complex situation but still requiring specific skills to be handled.

In order to find points in common with the national driving training programmes and in view of developing a teaching methodology able to explain and disseminate a CAV culture, it is advisable that the highway environment set for the simulator includes the following features, which – for convenience – we describe below using the graphic currently adopted in ministerial driving license theory tests.

(Country specific features are listed where necessary for clarity)

2.3.8 Motorway signage Italy & UK

2.3.8.1 Motorway emergency refuge area on smart motorway

These present clear risk to all road users, in particular with vehicles re-emerging to join flowing traffic. Testing this within the HSS should enable trainers to better understand how drivers will react to higher levels of autonomy and judge their acceptance in these stressful situations.

Figure 6. A. UK Motorway refuge area with signage B. Italian signage for refuge area.

2.3.8.2 Roadworks's contraflow system

The sudden change of traffic situation to incorporate 2-way traffic flow within the same carriageway may create added stresses on the driver who may choose or feel like they need to resume control from the CAV. Judging this interaction within the HSS would enable trainers to better plan future driver training modules.

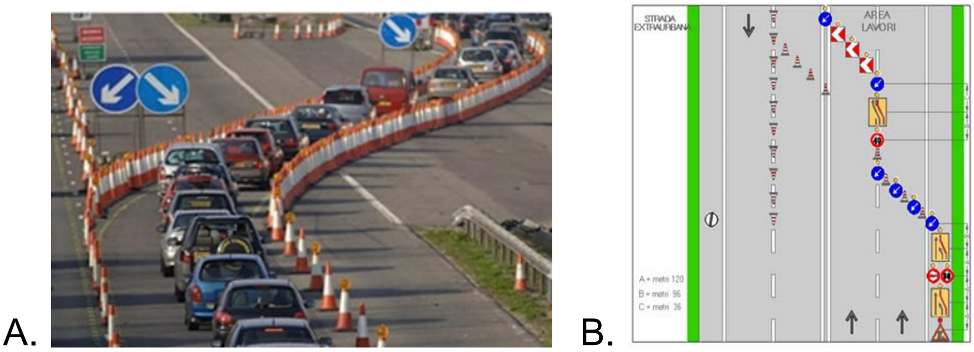

Figure 7. A. UK motorway contraflow B. Italian signage for contraflow.

2.3.8.3Tunnel

When approaching a tunnel, the speed limit will often change, and this feature can present driver challenges, hence its inclusion within road layout framework. Opportunity to assess driver acceptance of autonomy as the vehicle responds to the changes in speed limits.

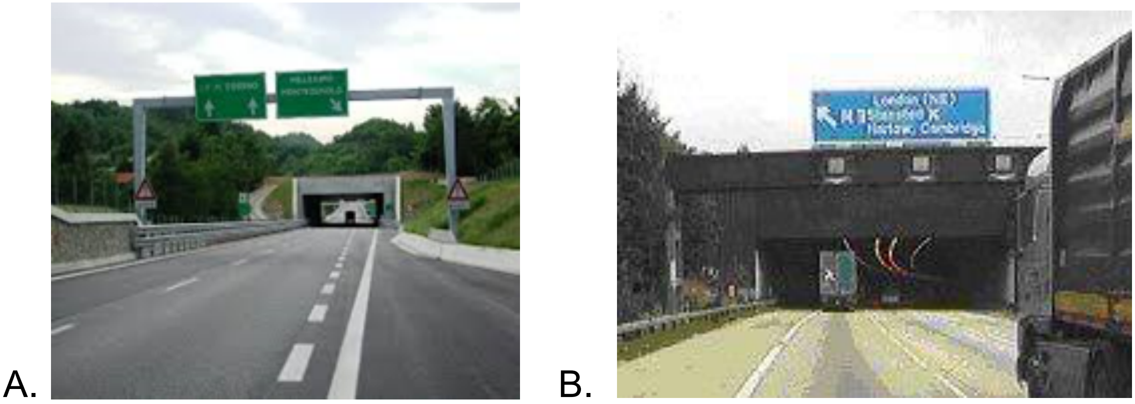

Figure 8. A. Italian tunnel approach B. UK motorway tunnel approach.

2.3.8.4 Emergency lane closure in an active lane for accident

In all running lane situations, a sudden incident or accident can create unexpected risk for the driver, and requires a particular level of awareness, that needs to be tested in order to allow trainers to establish how best practice techniques can be applied within a CAV training environment at different levels of autonomy.

Figure 9. A. UK All running lane motorway with accident
B. Italy Emergency lane closure on motorway.

2.3.8.5 Roadworks's lane closure

Lane closure in place, with reduced 50 mph speed limit. Like other incidents above, a sudden change to the number of available lanes may require more input from the human driver when the vehicle is traveling in autonomous mode.

A.

B.

Figure 10. A. *UK lane closure signs* B. *Italy lane closure sign.*

2.3.8.6 Fog

It would be important to test driver's acceptance of CAV's within different weather conditions, especially in fog, when visibility can be seriously restricted, thus increasing not only the objective danger of the situation but also the driver's insecurity.

Figure 11. Fog conditions on a motorway - provided to the simulator build team for reference.

The three features portrayed – autonomy levels, driver factors and driving environment - will be the basis of WP5 testing, with the help of the HSS, to allow the analysis of the behaviours and reactions of drivers in critical situations, thus deriving useful information for the development of a CAV dedicated training methodology.

However, WP5 can and will also rely on useful results deriving from the tests carried out with the other simulators in WP4. Useful information may be expected, for example, from the UBFC "driving simulator" and the University of Liverpool flight simulator, which concentrate on the observation of drivers' behaviour in CAV as well.

3 Competence and cognitive models of CAV drivers

Following the Section 2 Requirements of a CAV environment, this third section is articulated in four parts.

The first sub-section is dedicated to the building process of the CAV competence and cognitive models (structure and definitions of key components). These models illustrate what a driver should master and how a driver should behave to drive safely a CAV in both urban and highway environment previously mentioned.

The second sub-section will address the HSS tests carried out on the three partners (ACI, RDS and LIST).

The third and fourth sub-sections will present respectively the CAV competence model and the CAV cognitive and affective model inspired by the literature and HSS tests' feedbacks.

3.1 Building process of the CAV competence and cognitive models

As the goal of this deliverable is not to revamp the current Driving school training modules with only a minor “autonomous flavour”, we started the models' design from scratch with a literature review, as shown in Figure 12.
A systematic review of the literature was conducted in Elsevier and ScienceDirect from the earliest available date to September 2021.
During its development phase, the HSS was tested by LIST’s, ACI’s and RDS experts. From July 2021, most WP5 partners tested the HSS in different conditions (L3/4, urban/highway environment, with trainees and driving instructors), and a feedback workshop took place in September 2021. Driving instructors’ partners shared their insight from the tests they made with learner and professional drivers and drew several hypotheses between CAV driving and their current non-autonomous training programmes.
Finally, from July to September 2021, a controlled experiment at LIST premises took place.

As detailed in the upcoming section, an additional step might happen in the coming months, designing an updated version of the models.

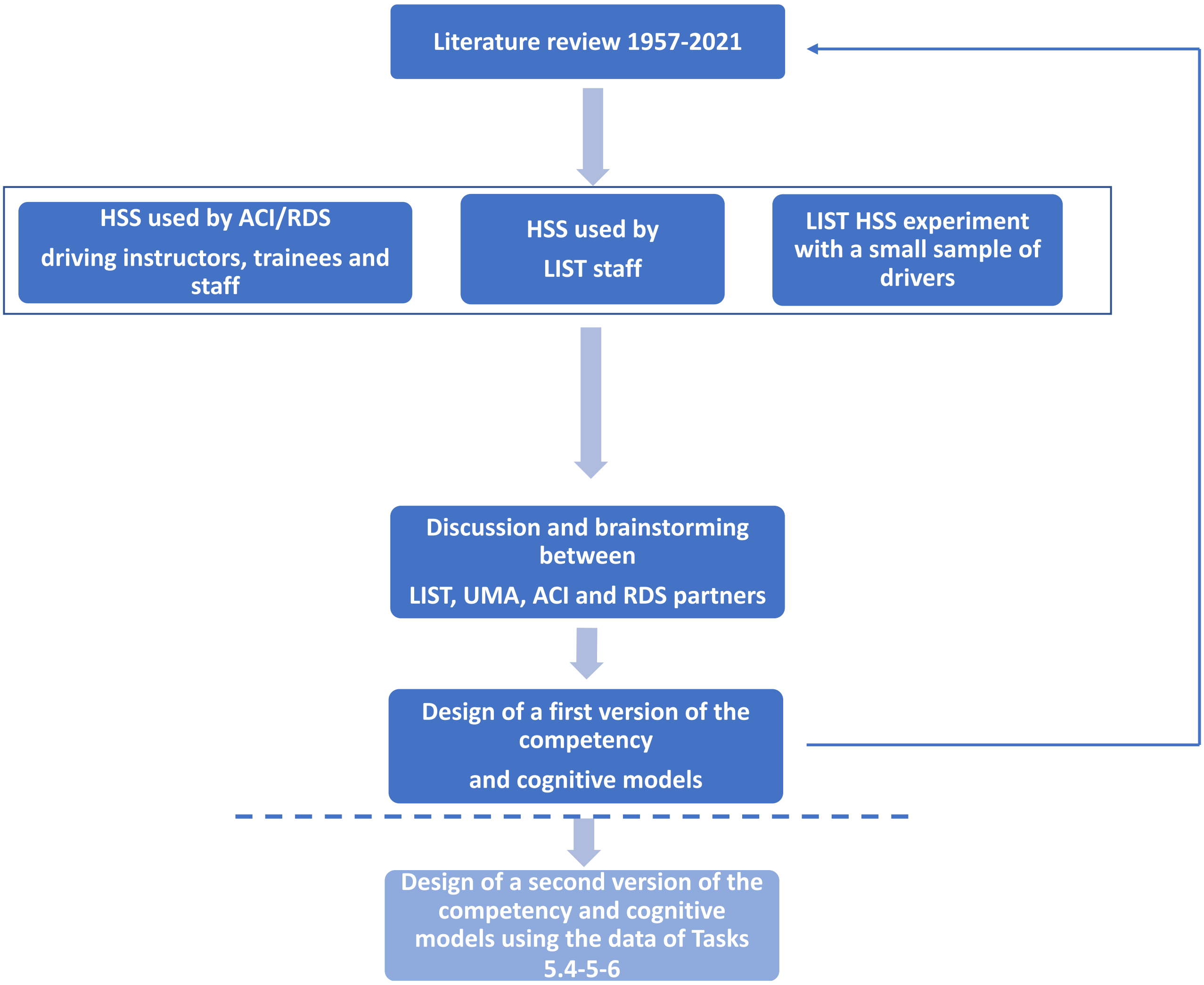

Figure 12. Summary of the models' design process.

3.1.1 The CAV competence model structure

There are thousand competence model definitions and structures possible. Following a consensual definition (Winterton et al., 2005), a competence model could refer to collections of knowledge, skills, abilities, behavioural elements, and other characteristics. The main components of our model will be Knowledge and skills relevant to perform in a CAV driving task (Campion et al. 2011).

If the model's *content* is king, we put effort to define a competence model *structure* that gives enough freedom to translate competence and cognitive models into training modules to its first "end-users": the driving instructors. “Who the model is being developed for and how it will be used” (Lucia & Lepsinger, 1999) is indeed essential.

The competence and cognitive models defined are simple (but not simplistic) with limited categories and a limited number of elements. Exhaustivity desire could lead to over-complexity and be finally counterproductive (Campion et al., 2011).

To build it, we applied four design best practices (Campion et al., 2011).

- The CAV **competence model** of drivers must **contribute to** enhance driver behaviour and acceptance of CAV and **the WP5 overall goal**.

Therefore, we shaped the model to facilitate the investigation of driver training needs and training solutions. We will consider the manual driving period (common procedural skills) and the autonomous period (before, during and after a mode transition).

- **Competences “anatomy”**

The structure of a competence can be defined through its main components and how it worked. A competence should be expressed through a 1) short title; self-explanatory enough to be easily used by the end-users (e.g. driving instructors); 2) a competence typology ranging from declarative knowledge, skills and 3) a description of the levels of proficiency on the competence.

As the primary use of the competence model will be to feed training modules, the proficiency criteria and how to assess them must be compatible with the UK Driving approach (“fault-based”[1]), which is also consistent with the Italian approach. Each competence (primarily procedural skills) should translate into behaviour (measurable during a practical driving-test with the HSS) or a knowledge test.

During future driving schools’ assessments, three ratings (or close to) could be applied for each behaviour or knowledge: success, minor fault (not potentially dangerous) and major (serious and dangerous) fault. As the model is mainly based on a qualitative study with a small sample that does not allow generalizability, it would be premature to define a detailed description of assessment items or faults of every component. PAsCAL Partners should do it during upcoming tasks.

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[1] https://www.gov.uk/driving-test/driving-test-faults-result

- **Achieving the proper level of granularity**

This best practice is the most difficult challenge in developing competence models. As detail could be helpful to derive training modules, parsimony is also needed to facilitate the appropriation of the document by the end-user and let freedom to people in charge of the following steps. Subjective exhaustivity of the competence model could limit the creativity and relevance of its future use (training definition here). Moreover, “there really is no ideal number of competences” (Campion et al., 2011). Therefore, we aimed to define around 20 to 30 competences (or components).

There is no ordering or weighting of the competences in the competence model (displayed on Section 3.3.2). In other words, Situation Awareness (SA), one of the competences enlisted, will not be ranked as the first competence in the model, even if we consider it as key. Every competence is needed to drive safely.

- **Maintaining the validity of competences over time**

As great resources are involved in developing and implementing a competence model and its close parent, the training model, “equal consideration should be given to maintaining the currency and usefulness of the models over time” (Campion et al., 2011). A significant weakness of competence models is that they tend to be static photography, quickly outdated and even erroneous. It is especially true when considering the rapidly growing body of literature and knowledge in the Automation and Human factors domains.

A maintenance process should then be considered with at least one iteration before the end of the PAsCAL project (the bottom part of Figure 12). Thanks to iterative loops between Task 5.3 and 5.4/5.5/5.6 (and maybe with other WPs), every model should have at least a second version. The first version of the competence model is partly built by observing a small sample of drivers. A second version might greatly benefit from extensive data of the upcoming tasks and its 270 subjects’ sample.

3.1.2 Definitions of the CAV competence model's categories

The CAV competence model is built in a manner that facilitates ease of use for the upcoming WP5 tasks. The competence and cognitive model will be inputs to develop a specific training programme for trainers, drivers, and professional drivers in the HSS CAV environment.

The competence model structure is broken down into six categories:

1. Competence number
2. CAV competence title
3. Competence type
4. Miscellaneous
5. References
6. Training challenges fit

These categories are described below.

Competence **numbers** ease their use and discussion.

The CAV **competence titles** are ideally short and self-explanatory for the driving instructors. As an intermediary document, the competence model will feed the training modules for the final end-user: the drivers. Either action verbs are used (imperative tense) when dealing with a skill (e.g. Do mirror checks), either common words are used when dealing with Knowledge (e.g. Knowledge or the CAV limitations).

The **competence type** category has two options: declarative knowledge and procedural skills.

Declarative knowledge is “static knowledge about facts, concepts and principles that apply within a certain domain” (De Jong & Ferguson-Hessler, 1996). In this deliverable, it means for example, the knowledge a driver must know to drive the CAV (e.g. Knowledge of the CAV capabilities).

We elicited on purpose a limited number of declarative knowledge to ease its appropriation. Pragmatic and action-oriented wording are favoured. Note that every skill could be broken down into multiple declarative knowledge (and cognitive components) to be mastered. But parsimony is, again, a best practice to follow.

Procedural skills could be actions or manipulations useful for a domain. In this deliverable, it is the skills needed by the drivers to drive safely their vehicle (Ebnali et al., 2019).

The **Miscellaneous** category contains various elements. According to feedback collected during the HSS test from drivers, according to literature excerpts and WP5 Partners' contribution, these elements should ease the appropriation of the model by the driving instructors.

The **References** category displays the source inspiration of the competence, usually from a scientific document. The goal is not to be exhaustive.

The last category of the competence model highlights four CAV **Training challenges** (Merriman et al., 2021), detailed in Section 3.3.
This last category helps us to highlight critical themes to consider in our model. These challenges could also be an inspiration to define future training modules. Moreover, as we discovered this article at the end of our design process (we achieved 95% of the literature review), it was used to counter-validate the content defined, without knowing in advance the main elements to consider. Only a few details were added or updated, thanks to this article.

Some competences might fit one or several of the four training challenges, inspired by Merriman et al. article. Some of the competences may even fit every four challenges, but only the most relevant Training Challenge-Competence link(s) will be displayed.

Initially, two additional categories were displayed in our competence model: SAE level tested with the simulator (3 and 4) and the Road environment (urban or highway).

The HSS test run at LIST, in the WP5 scope, plans to collect around 25 driver's data. Due to cascading effects (challenges mentioned in Section 1.4), only 10 of the 25 persons objective has been achieved in the timing initially foreseen. Due to limited data from the WP5 HSS LIST experiment that diminished our conclusion's generalisability (mitigated by the literature review) and due to pending questions, we chose to remove these categories.

In a preliminary version of the model (including the removed categories), most of the competences were relevant for both SAE levels 3 and 4 and both driving environments. If almost 100% of a competence model ticked each option or criteria of a category, it means that these categories are not worth to be mentioned.

This conclusion points out that our competence model is generic (which was one of the purposes) and that the granularity of competences defined is always a challenge. Should we have broken down each competence into four sub-competences? This would mean that, for a 20 or 30 elements competence model, this would have increased its size to 80 or 120 elements, which is against all best practices. Our choice to have a limited number of competences is a compromise between “over-complexity” and “over-genericity”.

Thanks to potential future results, if sound data are collected in WP5 upcoming tasks, we might decide to put back the previously removed categories in a second version of the competence model.

Some of the pending questions are related to the SAE levels and their consideration in the HSS. During the experiment, note that we used the SAE taxonomy in its 2018 version (Society of Automotive Engineers, 2018).

Even though LIST experiment’s subjects have received the same training session before starting the experiment (see 3.2.2), the first feedbacks show that the perception of the L3 and L4 CAV capabilities and limitations is different from person to person.

For the sake of future training sessions, it will therefore be necessary to have a clear statement and an in-depth explanation of our vision and interpretation of each level available when using a CAV.

These misunderstandings are not surprising, as mentioned in Section 2.1. Automation levels are essential but complex CAV requirements in studies, including WP5 tests. From a practitioner point of view, the SAE taxonomy makes people “believe SAE Levels of Automation need to be discarded and replaced” (Aspelt, 2019). Moreover, the same experts highlight “the differences between level 3 and 4 are so subtle […] as to be entirely academic and add no value”.

From an academic point of view, SAE taxonomy is also unsurprisingly a source of debate (Stayton & Stilgoe, 2020).
Note that thanks to the last SAE taxonomy 2021 update (Society of Automotive Engineers, 2021), available after some of the HSS tests, this last version might help refine our competence and cognitive models according to the specific autonomy levels we consider the HSS and therefore ease the training development.

As the HSS tests are one key input defining the competence and cognitive models, we will now detail it.

3.2 Home Study Simulator tests

A series of tests with the Home Study Simulator is ongoing in Italy, UK, and Luxemburg to collect inputs and feedbacks from, on one side, trainers, and instructors, and on the other side, the professional and experienced/learner drivers.
This deliverable use available results to date, and we plan to use upcoming results, which will be summarized in the D5.2 and D5.3.

3.2.1 ACI and RDS Driving School tests

The WP5 description is quite detailed about the tests that driving schools will conduct. As planned, the tests will be performed on 160 participants, 140 novice/experienced drivers and 20 trainers in the UK and in Italy and 25 professional drivers, in Italy only, as follows:

1. 80 participants without trainer: 40 for CAV L3 eco/sport + 40 for CAV L4 eco/sport
2. 80 participants with trainer: 40 for CAV L3 eco/sport + 40 for CAV L4 eco/sport

The 20 trainers who will then also carry out tests on other drivers' categories.
ACI will carry out the tests across five cities. In this initial phase, three driving schools have been selected in the provinces of Lecco, Modena, and Savona. These driving schools have offices scattered throughout the province; hence testers will be recruited in different towns.
Due to its different organisational model, RDS will carry out all test in the UK at its “Red Driving School national training centre” located in Donnington and will draw its candidates from 5 local towns and cities.

As soon as the HSS development reached a level acceptable with the use in driving schools, the testing phase has started, and initial outcome was discussed during the Trainer Workshop on September 7th, 2021.

The Workshop was meant as the first of a series of workshop involving WP5 partners and driving trainers/instructors cooperating to the project aimed at discussing and analysing the specific driving training issues and topics pre-identified and/or emerging from the tests.

The discussion involved from the academic side also UBFC, in order to compare, as much as possible, experience and results of the test carried out in WP4 using a different driving simulator.

Being the first meeting, the workshops' goal was to:

1. Share experiences and outcomes of the tests carried out so far.
2. Identify problems and their solutions.
3. Identify specific topics which need more careful examination.

Due to a series of circumstances (the HSS was finally released mid-July 2021, Covid 19 contingencies, summer holiday period during which the workload of driving schools physiologically decreases), the number of tests carried out up to September 7 was still quite low, and mainly focused on trainers:

Table 1. *Descriptive statistics of ACI and RDS testers up to September 7th*

	Trainers / instructors	**Professional drivers**	**Novice/experienced drivers**
UK	12		24
Italy	14	35	4

In spite of the low number of tests, the outcomes of the workshop were quite promising, though, of course still interlocutory.

The analysis of the tests, their outcomes, and the perceptions of the observers, both academic and driving schools' professionals tend to coincide.

Age is an important variable. Learner drivers tend to trust the autonomous drive more than experienced drivers. Also, among expert/professional drivers, younger drivers accustomed to technology have a more casual approach and more confidence in autonomy. Older drivers had a tendency to intervene anticipating the autonomous driving. This causes a higher level of stress.

Practice is mandatory. Testers needed some practice to become confident with the HSS and, in parallel, with the autonomous driving. The use of simulators by driving schools in their driving training, I.e., ACI's Ready2Go Network, aims at improving the practice and learning of driving automatisms without any risk. However, attention needs to be paid to the fact that simulations may be perceived by the testers as not "real", as a game, not perceiving speed and situations as dangerous thus not really "caring" about misbehaviours which may be dangerous on a real road.
This effect has been verified also in the PAsCAL tests carried out in driving schools. After about 4 tests carried out, trainees tend to get used to wrong behaviours, repeating the same misbehaviours (e.g. not signalizing the change of direction) without showing awareness of how such a behavior may be dangerous in reality. It has also been confirmed during LIST tests. This need to be considered in future testing and training (as detailed in Section 3.3.5).
On the other hand, it was also observed that after some testing, trainees tend to get used to the intervention of autonomous drive, thus relying more on the automatic system. But reducing the level of attention and therefore the ability to respond to the solicitation of the road. This needs further, careful consideration.

HMI make a difference. For an effective training and future use, HMI should be user friendly and very similar throughout different vehicle models, to avoid confusion and uncertainty among users who need to be able to use the different devices out of practice, without consciously thinking about them. European and National authorities should promote the quick definition of common standards and guidelines for OEMs.
Both learner and experienced/professional drivers showed difficulties in switching from autonomous to manual mode in the Highway scenario. This is partly due to the fact in the highway environment that driver has fewer stimuli, a lower degree of attention and consequently a different speed of reaction. However, this needs careful consideration with a view to developing a training methodology.
One option which could be considered is the possibility to introduce specific "tasks" to keep the driver's alert enough to react in a suitable manner.

<u>Autonomous functions need to be studied in depth</u>. Before giving full confidence to autonomous driving, it is necessary to understand the vehicles' functions, limitations, and benefits as well as all situations which may be encountered in a mixed traffic environment (see Mental model section 3.3.1).

If it may not be necessary to develop two training methodologies, one dedicated to expert/professional drivers, who are well accustomed with manual driving and need to fully understand the functioning of the autonomous mode in order to trust it, and one dedicated to learner drivers who will appreciate the autonomous driving but who will lack the necessary manual skills to correctly drive the vehicle once compelled to regain control. However, it may be advisable to develop a very thorough theoretical training methodology and compulsory, continuous L3 and L4 training.

3.2.2LIST tests

The LIST experiment aims to expose drivers to four HSS driving sessions. The overall process (handled in WP4) is detailed in Annexe 2.

In addition to WP4 objectives, these sessions are helpful to understand the driver behaviour and derive cognitive and competence requirements. As described in D4.1, subjects are exposed to various situations, including pedestrians crossing the road, crossroads, and automation mode change (see below Figures 13 to 18).

Figure 13. Manual Stage in a suburb.

Figure 14. Single Lane Urban Road with a vehicle pulling out from the right.

Figure 15. Single Lane Roundabout.

Figure 16. Dual Lane roundabout.

Figure 17. Pedestrians crossing from behind a bus.

Figure 18. Dual Lane Urban Road.

The GPS navigation system is included and can be seen in the previous figures. A red line indicates the desired route, along with a dot that indicates the car's position concerning the route and surrounding streets. The interface also shows the current vehicle mode (green symbol on the top left) and if the automated mode is possible at that location. The current speed limit is also displayed if the vehicle is in eco or sport mode.

The scenario involves the subjects experiencing manual driving, followed by autonomous mode, where they need to take back control of the vehicle at various points when the automated system cannot handle a particular situation. For example, when there is a pedestrian crossing from behind a bus or a poor connection to other vehicles. The vehicle then resumes automated mode when it is safe to do so. If the driver does not take back control (by pressing a steering wheel’s button), the car will automatically park in a safe place. During the training, drivers were informed about the duration the CAV allowed letting the driver takeover and what would happen if they did not react.

The urban environment consists of three different routes, and each driver experiences these in eco mode. They experience three primary phases within each route: an initial manual driving step, an automated area (with mode shift changes), and a destination point where they park. In common with the example suggestions from the SAE taxonomy (SAE, 2018), the vehicle can operate in level 4 only within a designed area and when all safety conditions are met.

The basic components of the scenario include everyday traffic situations which ACI and RED driving instructors specified.

For this experiment and according to the D5.1 objective, the target is around 25 subjects. Subjects should be recruited internally (at LIST) and externally in the Esch-Belval area in Luxembourg, considering gender balance and age diversity. Note that external people receive a 50 € voucher as an incentive.

From two to six weeks, drivers attend four sessions and are recorded approximately for two hours and 15 minutes broken into:

- 15 minutes training session (including the SAE levels presentation) + 30 minutes driving test
- 30 minutes driving test
- 30 minutes driving test
- 30 minutes driving test

No guidance about the opportunity to engage in non-driving-related task (NDRT) was mentioned to the drivers. As an exploratory observation, we wanted to see the spontaneous behaviour of drivers (mind on or off, hands on/off, etc.). Nevertheless, general guidance of safety and respect of road rules have been given before each driving session.

3.2.3Home Study Simulator environment

The HSS setup comprises a Logitech steering wheel and pedals (zoomed at the left side of Figure 19). On the right side of the figure is displayed the current configuration (LIST premises) with the table, chair, and screen used in current conditions.

Figure 19. HSS setup on LIST premises.

3.2.4Simulation Design

An urban environment was built, along with a suburban area. Within this, three main routes are provided. The overall urban area is approximately 64km2. Each route lasts around thirty minutes and can be in various traffic and driving (eco vs sport) modes. There are about 40 different tasks (e.g., crossroads, junctions etc.), and at specific points, the driver is asked to take back or give back control of the vehicle.

As seen in the abovementioned Figures 14 to 19, only the left and rear-view mirror are directly visible by the driver. To see the right mirror, the subject can use several buttons on the steering wheel:

1. either with a short pressure on a button to have a quick look at the right mirror (head moving briefly to the right and coming back centred),

2. either with a constant pressure on another button to move the screen on the right. It implies that the driver must push another button to centre back the view.

A similar process is needed (buttons to push) to move the driver's head (i.e., on the screen) to look at blind spots. These "low-realistic actions" to perform were strictly mentioned during the training phase (first session) and repeated several times as it was foreseen to be a potential source of error (in terms of safe driving and respect of the MPM routine).
Specific HSS features will be detailed in the Miscellaneous category of the competence model table (Section 3.3.5).

Additional details about the HSS Simulation Design are available in the D4.1.

3.2.5Measurement package

The LIST experiment served some of the WP4 objectives and the D5.1 goal. For this D5.1, we only used part of the WP4 measurement package: driving observation data and the Nasa TLX results, with a limited sample. Ongoing tests (in WP4) and future tests (T5.4, 5, and 6), in addition to the analysis made in WP 4 (acceptance questionnaire, rep grid, telemetry data, etc.), with much bigger samples, may allow us to reach generalizability to amend the first version of the competence and cognitive models.

3.2.5.1Nasa TLX questionnaire

The Nasa TLX questionnaire (Hart & Staveland, 1988) is a cognitive workload questionnaire used in experimental studies. The questionnaire is broken down into seven sub-scales, allowing subjects to rate their experience from 1 to 21.
For this deliverable, we choose to only consider the 7 sub-scores of the NASA TLX and not the global score. Indeed, driving situation complexity (e.g., a junction could be different to roundabout in terms of workload), driving experience, and other factors may have different impact, and therefore decrease the usefulness of a global score (Galy et al., 2018). Despite its sub-scales, note that the Nasa TLX is still an overall evaluation of the *overall* driving task. Specific cognitive workload assessment per event (one for a roundabout, one for a junction, etc.) could be considered in future studies if relevant.

Even if our preliminary results are based on a small sample (8 subjects), and great caution is needed in terms of analysis, few statistics are worthy presenting. See annexe 1 for exhaustive results (descriptive statistics, correlations between NASA TLX sub-scales).

Based on our current results, every sub-scale (except the Physical demand scale) has a significant and positive correlation with the other sub-scales.

As attitudes, cognitive and emotions states could be determinants of the driving performance, we want to highlight the four strong links (called bivariate correlation in statistics) between the **Frustration** sub-scale and other sub-scales:

- Positive correlation with the Temporal demand scale (r = .75; p < 0,001).
- Positive correlation with the Effort to accomplish the performance scale (r = .54; p = 0,003).
- Positive correlation with the Performance scale (r = .52; p = 0,005).
- Positive correlation with the Mental demand scale (r = .49; p = 0,009).

A large positive correlation between Frustration and Temporal demand results means for example that when a driver gave a high rating in terms of Frustration (i.e. the driving task was frustrating), most of the time, the driver also gave a high rating in terms of Temporal demand (i.e. driver felt time pressure due to the high pace of tasks). A correlation does not mean there is causality, it only means there is a link.

These preliminary results are a first step of our analysis. Thanks to bigger samples and additional data, we hope to be able, with empirical data, to highlight which components (or combination of components) might explain most of the variance and be, therefore, points of interest in terms of training.

3.2.5.2Observation and videos annotation

Each LIST experiment driving session is managed and observed by at least one LIST PAsCAL member. An observation sheet is used as a first data collection mean (see Annex 3) to collect multiple elements (behaviours and related competences, affective reactions, etc.) to feed the competence and cognitive models.

In addition to the manual observation of the subject (behind his back), camera recording is also used as a complementary analysis.

Figure 20 shows for example, a session in which four cameras have been used to capture face reactions and body movements (hands, legs, and feet). Depending on the driver, drivers wore masks or not, impacting the ease to analyse drivers' reactions.

Figure 20. Synchronized four cameras used during the LIST experiment.

Cross-validation of annotated videos

Though the competence model focuses on cognitions involved in driving activities, it is of utmost importance to integrate affective reactions. As is known from the cognitive sciences, cognitions are heavily dependent on affective states including basic emotions on the one hand (i.e. joy, fear, sadness, disgust, anger, surprise), but also on secondary emotions such as shame or guilt (see 3.4.2 for a detailed explanation). That said, the aim of the video analyses is to have coders classify participants' affective reactions to critical events during the simulator ride. For that purpose, we defined the perspectives of interest needed to observe relevant behaviours and expressions.

After data collection is complete, these videos will be segmented to obtain episodes of interest base on stimulus input and driver behavior. The video material will be analysed by two independent trained raters following a standardized coding scheme to ensure a reliable assessment of affective reactions as a function of stimulus input (traffic situation) on the one hand, and driver behavior on the other.

3.3 The CAV competence model

Before defining the competence model, we first defined a generic CAV safe driving meta-model (Figure 21), structurally inspired by the DEC model (Lindstrom-Forneri et al., 2010).

3.3.1 The CAV safe driving meta-model

This meta-model is broken down into:

- Personal factors, including cognitive and emotional factors that will be detailed in the cognitive and affective instance model
- Moderators which are factors that will have (positive or negative impact) on the CAV competence.
- Environmental and physical factors (physical CAV features)
- The CAV Driving competence which will be detailed in a specific competence instance model (Figure 22 and then Table 2).
- And the output of the model: the ability to perform a CAV safe driving.

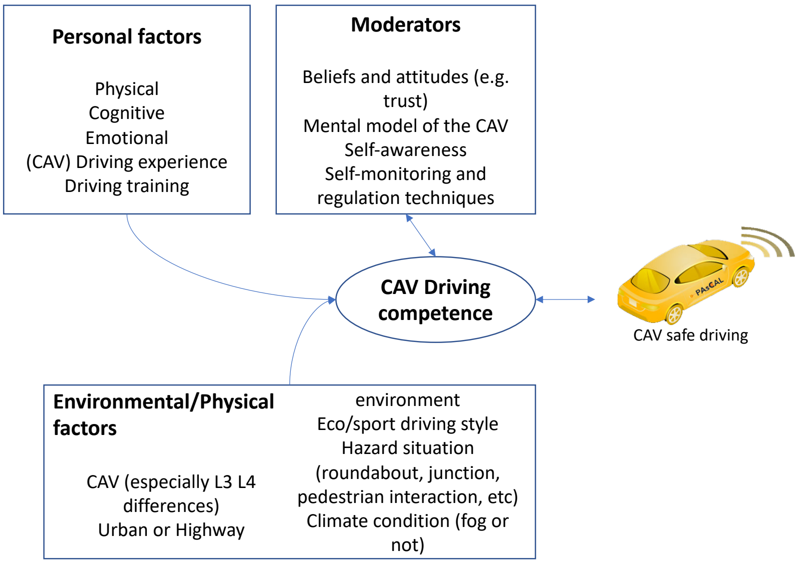

Figure 21. The CAV safe driving meta-model.

Following this broad meta-model, we will now detail its first sub-instance, the CAV competence model, displayed in Figure 22.

3.3.2The CAV competence model

For the sake of conciseness, the competence model (Figure 22 below) displays the 20 competencies blocks (e.g. C1, C2, C20) and the four main competence domains.

- Mental model of the CAV capabilities and limitations
- Ensure an optimal cognitive workload of the driver
- Target positive attitude towards automation and the CAV
- Mastery of procedural and hazard perception skills

Later in this document (in Table 2 and in sections 3.3.2.1 to 3.3.2.4), the 20 competences of the model are detailed.

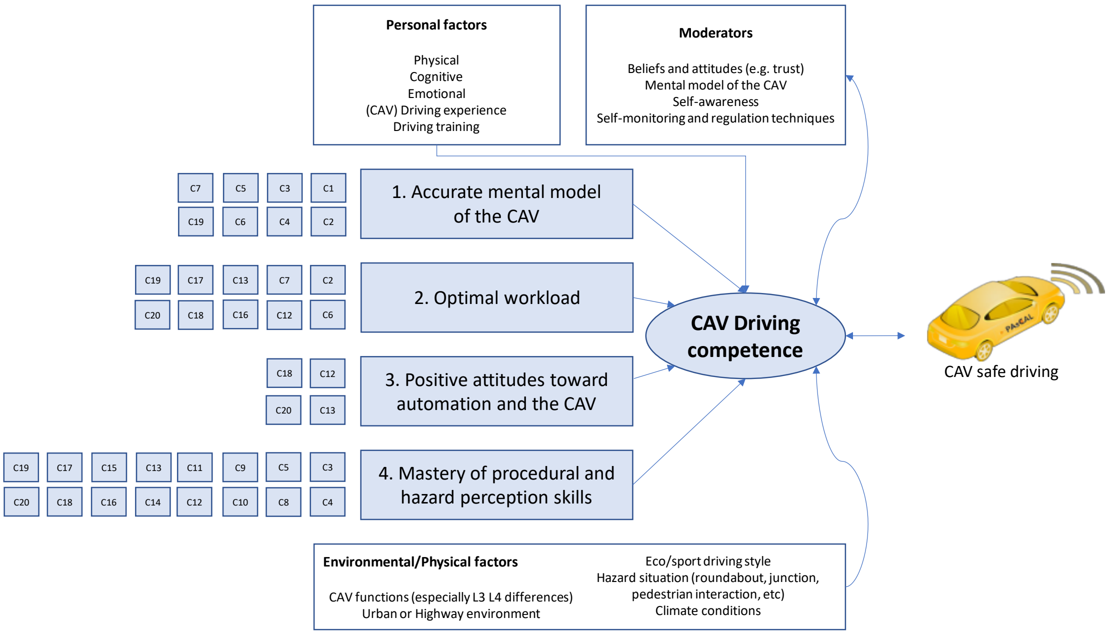

Figure 22. The CAV competence model with the four main competence domain and the 20 competencies linked

In the following sub-sections, specific details will be given with regard to the HSS but the overall scope of the CAV competence model is generic enough to answer many CAV training needs, whatever the type of CAV (a simulator or vehicle).
In addition to the tests made by ACI, RDS and LIST, a great source of inspiration for the CAV competence model comes from two primary sources.

The first one is related to driver training for CAVs (Shaw et al. 2020). To the best of our knowledge, it is one of the most recent training study and report publicly available. Therefore, there is no surprise that several competences enlisted in our model take inspiration from it.

The second main source of inspiration for our model is a study that present a framework that “can be used to develop and test a training programme for drivers of Automated Vehicles” (Merriman et al., 2021), 2021). A great fit with the objective of this deliverable and the upcoming deliverable 5.2 and 5.3. This second source, which we discovered recently, helped us to counter-validate per se our initial CAV competence and cognitive models. Merriman et al. mentioned four main challenges of CAVs training, which we adapted to our CAV competence model (Figure 22). These four training challenges are translated into four key competence domains. These four blue blocks will then be detailed in table 2.

Each atomic element of the competence model, linked to each of the four main challenges, is displayed at Section 3.3.5. Several elements (e.g. reference) are added to ease its use, as mentioned in Section 3.1.1.

In terms of scope of the competence model, manual driving competences and CAV driving competences are considered.

As mentioned in Merriman et al. (2021) article, most of the CAVs training reviewed neglected manual driving. Every PAsCAL partner agrees with this need to consider manual skills. From an empirical point of view, during LIST experiment, subjects sometimes failed to apply basic manual driving skills. Manual skills they said they perfectly master in real life.

How should we explain this failure or faults? Because of the need to master new CAV competences and perform new behaviours? As an indirect effect of the use of the HSS (with specific HMI)? Or as a common Dunning Kruger effect (Kruger & Dunning, 1999)? Without enough empirical data, this question remains unsolved.

We will now detail the 4 key competence domains which will tackle the 4 key CAV training needs.

3.3.2.1 *Update the poor mental model of the CAV capabilities and limitations*

CAV mental models are the representation (true or false) of representation and understanding drivers have about the CAV. It includes the way the CAV works, what it is capable of doing, what it cannot do, what are the different features, what are the interaction between a driver and the CAV, etc.

An accurate CAV mental model has several advantages (Forster, Hergeth, Naujoks, Beggiato, Krems, & Keinath, 2019). It will allow safer driving by increasing knowledge, procedural skills and underlying cognitive and affective abilities (Merriman et al., 2021) and probably increased trust and acceptance.

The LIST experiment highlighted one possible detrimental effect of an erroneous mental model of how the CAV (HSS here) works. A subject used a button to move the screen on the right side to see the right mirror, but he forgot to push another button to centre back the view. He drove several minutes with a non-centred view which led to a limited SA.

Another example of the risk of an erroneous CAV mental model is related to the complacency bias (Wickens et al., 2015). A subject, a bit sleepy after automation, missed the request to intervene signal, and then the car parked itself. It is not a danger as the HSS took care of the safety, but it highlights the lack of knowledge and attention of the driver and the related bias and (missing) behaviour.

If drivers should self-assess their mental model to dynamically update it, they will greatly benefit from the driving instructors' guidance to do so. Self-evaluation skill has been known for decades as a pivotal element in driving, as shown in the EU-funded research project Gadget (Peräaho et al., 2003).

Simulated on-road practice and classroom activities (with knowledge tests) are relevant training options to improve the mental models of drivers.

Competences 1 to 7 and competence 19 fit this challenge (see Table 2 and Figure 22).

3.3.2.2Ensure an optimal cognitive workload of the driver

Mental or cognitive workload are the quantity of the resources used during the driving task, either as a Driver Driving or as a Driver monitoring (Endsley, 2015) with CAVs.

As the HSS will control some of the tasks usually made by a driver, the workload might be lower in some tasks. As the driver's attention might be decreased due to automation (Endsley, 2017), it can be detrimental to driving performance when the CAV is no more able to perform and a takeover is needed. Reaction time, perception abilities and therefore manoeuvres (Bueno et al., 2016) can be negatively impacted.

As an example of the interdependencies with the previous training challenge - have an accurate mental model - the link with optimal workload training challenge is evident. If the CAV mental model of the driver, he should be able to better focus his attention on relevant tasks (knowing

what he has to do and what the HSS will do), allowing better perception, understanding and decision making (quicker and safer).
Similarly, as for the need to self-assess and update its mental model, the CAV driver must self-assess his workload and, if needed, regulate it (Naragon-Gainey et al., 2017).

The current state of the driver (e.g. physical position, workload resources available, the position of the car, focused on the road or doing a NDRT etc.) and the skills related have to be dynamically checked and assessed by the driver to drive safely. As illustrated in Table 2, Shawn et al. (2020) highlighted the need to check several elements (road, the vehicle and driver itself), to assess them (compliant or not with safety rules) to take an appropriate decision (e.g. takeover or not). Therefore, drivers have to maintain a “positive state” related to every element abovementioned and summed up as ‘fitness to drive” (Naujoks et al., 2018) or ready to drive (from a physical and psychological point of view).
This training challenge will be considered in both models: the competence and cognitive models.

Competences 2, 6-7, 12-13 and 16 to 20 fit this challenge (see Table 2 and Figure 22).

3.3.2.3Target positive attitude towards automation and the CAV

The third challenge is related to the attitudes and the personality of drivers. As considered during our experiment (thanks to an acceptance questionnaire and the rep grid), attitudes could strongly impact acceptance and safety (Beggiato et al., 2015). The trust a driver about the CAV, for example, and the driver trust about its own competences (self-efficacy) is a challenging training gap to address.

Again, links with previous challenges are easy to draw for this third challenge. An accurate mental model of the CAV/HSS is related to the trust in the CAV’s purpose, in the CAV processes and in the CAV’s performance (Liu & Hiraoka, 2019). The calibration of trust in the CAV must be accurate as either low-trust or over-trust leads to errors.

To illustrate the importance of acceptance and trust in the performance of the CAV, we observed that several LIST experiment’s subjects considered the HSS right mirror as not efficient in terms of driving safety. This specific low trust of an HSS feature may have been detrimental to the driving performance. This trust issue also needs to be considered with the damaging effect in terms of road attention. Indeed, to perform a right mirror check, subjects had to look at the steering wheel to press a button, missing the screen/road for some time. As similarly seen in the literature (Manchon et al., 2021), subjects were surprised to see that the CAV (at L4) was not able to perform every task needed: they had to respond to a takeover request (TOR) several times. These takeovers requests tend to create a low trust at these moments.

CAV efficiency is one determinant of CAV acceptance and trust as confirmed in the literature and the D3.1. As detailed in Section 2, CAV acceptance is mandatory for CAV safe driving. D3.1 highlights that privacy, road safety, stress and enjoyment are the most important expected consequences of CAV usage. These factors can shape the CAV acceptance and consequently will impact the attitude a driver has about CAV and, to a certain extent, its driving performance. As guidelines to design a CAV and the PAsCAL HSS, D3.1 provides key points of interest to investigate during WP5 training.

Close to attitudes, personality has been studied in terms of driving styles (Esterhuyse, 2017; Oppenheim & Shinar, 2012; Taubman-Ben-Ari & Yehiel, 2012) and emotions (see Section 3.4.2).

For example, aggressive driving and anger (Deffenbacher et al., 2001, 2003) have been shown to be predictors of dangerous behaviours (loss of vehicle control). Driver attitudes, driver personality and driving styles are dependant variables to consider in terms of CAV design, CAV competencies to master and therefore CAV training to develop.

Raising self-awareness and self-assessment about driving attitudes and personality is essential for this third training challenge.

Competences 12-13, 18 and 20 fit this challenge (see Table 2 and Figure 22).

3.3.2.4Keep training the "old" procedural skills in addition to CAV skills

Even if the focus of any CAV training is mostly related to "new CAV competences", it is worth highlighting that manual driving skills (handle and manoeuvre) are essential.

As highlighted in the literature (Shaw et al., 2020) or seen during the LIST experiment's, several minor and major faults were strictly related to manual skills. Even after four sessions of HSS driving (out of 4), which means around 2 hours of CAV use, faults were still performed.

Procedural skills faults can be considered in two ways: faults close to an autonomous moment (before a takeover, during or after the takeover) and faults "far" from an autonomous or transition moment.
The first type has been shown in the literature, automation may lead to a low SA, for example. Training must address SA.
The second type of fault should also be considered. Several experiment's subjects failed to apply some basic safety rules (e.g. blinker use) during the first manual phases (at the beginning of sessions), meaning even before the first automation period. This lack of manual skill has been redundant during each first minute of the four sessions lived by some subjects. According to the range of age of the subjects, it cannot be explained by a sample composed mainly of learners or young drivers. Whatever the age, basic manual faults were performed.

As shown in the literature (Ebnali et al., 2019; Payre et al., 2017), simulator training (and hopefully with the HSS) is a relevant mean to enhance safety in terms of procedural skills and especially in takeover behaviour (e.g. to get lower speed variance and Standard Deviation of Lane Position).

Competences 3-5, 8 to 20 fit this challenge (see Table 2 and Figure 22).

In addition to manual procedural skills, a focus on competences related to request to intervene phases, autonomous driving phase and post-takeover phase are also necessary. During the LIST experiment, as the HSS was an unfamiliar situation, every subject had to get used to "unusual" features (e.g. a button to press to check the right mirror, blind spots). It leads several subjects to "forget" manual procedural rules and skills they master (or at least think) in an actual situation with a non-CAV.
Practice training to increase familiarity of a situation (environment and vehicle) (Lindstrom-Forneri et al., 2010) is an easy mean to increase driving competence.

Skill maintenance is needed for experienced or professional drivers. For learners or young drivers, acquiring and reinforcing skills might be the logical first step before maintenance.
For learner drivers, the application of the basic mirror check routine is not fully automated yet, and due to a lower mental capacity (part of it dedicated to the routine), it might be detrimental for another attention-demanding task like give attention to road signs, other vehicles (Sagberg & Bjørnskau, 2006), etc.

If our competence model lists several procedural skills, Situation Awareness (Endsley, 1995, 2015) is one of the most crucial skill domains to consider for CAV driving training.

3.3.2.4.1 Situation Awareness

Situation Awareness (SA) is “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (Endsley 1995, p. 36). If SA could be related to the capability of a system (e.g. a CAV and its limitations to deal with hazards), we will focus only on the human SA.

Endsley defined three levels of SA, perception, comprehension, and projection, prerequisites to make a relevant decision that leads to a safe CAV driving. This flow is displayed in Figure 23, inspired by the SA Endsley model (Endsley, 2019). As displayed, individual, task and environmental factors can play a key role in the driver’s SA, especially during takeover behaviours.

As described in Section 2, the requirements of the CAV environment – the urban and highway environments and their features (e.g. hazards or events, signage, weather) - are factors that will be considered in training to see how they can impact SA.

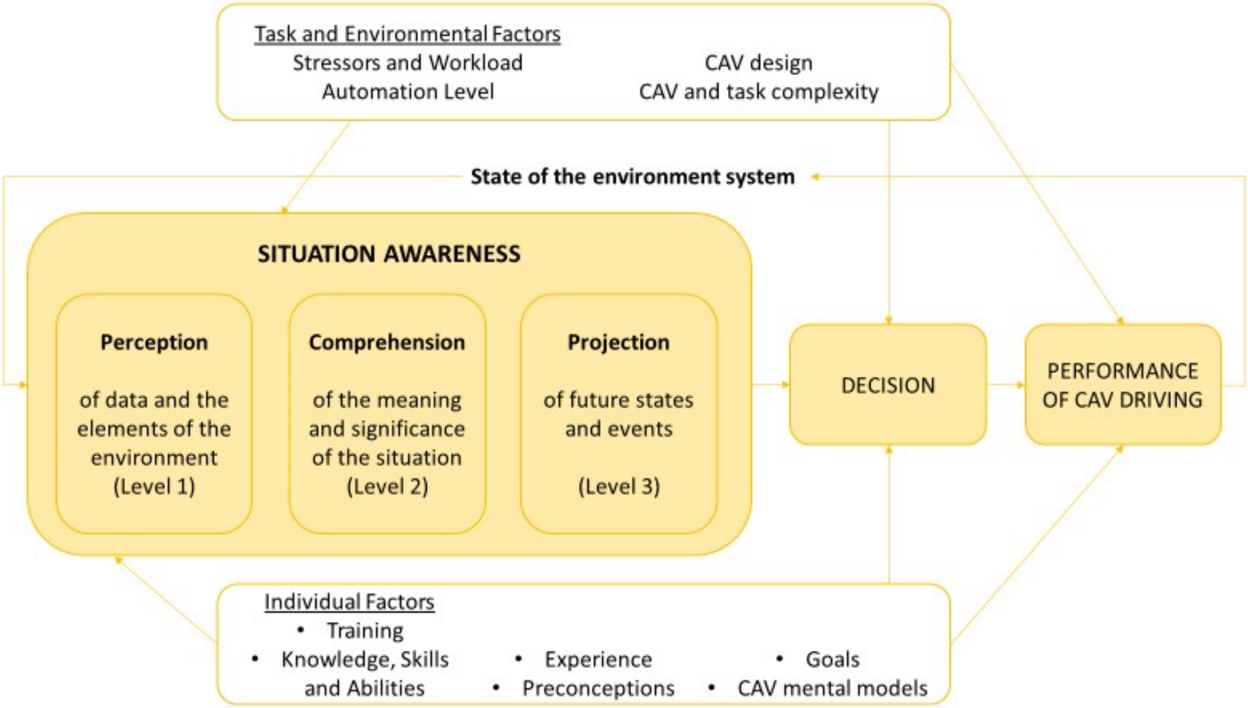

Figure 23. Situation Awareness model of CAV driving, inspired by Endsley model.

Ideally a driver should master the three SA levels; every level could be considered through training.
For example, in case of missing data related to Level 1 (perception of data, like the potential presence of a pedestrian), drivers could be able to master level 2 and 3 by applying Level 1 "default" data. A default data could be that a pedestrian might appear behind a bus, so the driver, being proactive (and not reactive), should decrease his speed to be safe. Without real data in terms of perception (the driver does not see the hidden pedestrian, but he makes a hypothesis), a driver might be able to understand the (potential) situation and related risk (Level 2). Finally, related to Level 3, the driver projects a future state (a risky situation which needs a speed adaptation) and then make the proper decision and action (brake) to drive safely.
Some drivers behave as passengers (less road attention) after automation period; to enhance safe driving, drivers should be proactive and not only reactive.

As SA is related to the overall environment and to the CAV, a driver must master several SA "facets": related to its own driver state, to the CAV/HSS state, to the road, to the other vehicles, to signage, etc.

In terms of practical implication of SA, a CAV training cannot for example neglect the application of classical safety routines, as the MSMPSL routine. MSMPSL stands for Mirrors, Signal, Manoeuvre. Manoeuvre is broken down into Position, Speed and Look. This routine fits with every type of critical situation a driver encountered during a HSS test, especially when a takeover is needed.
The full replication of the MSMPSL routine is not possible in the HSS as there is no centre mirror in the HSS. According to the number of faults we observed during the LIST tests or heard during post-driving feedback, the acquisition of this skill might be one of the hardest challenges. During LIST tests, contrary to other skills which benefit from the increasing experience of 4 sessions (e.g. a smoother use of pedals), the side-mirrors check (and the need to use a button) was still an issue at the end of the four sessions.

Contrary to non-CAV or low-level CAV (e.g. using ACC only), the HSS is a L3 and L4 CAV. It allows then the driver to perform NDRT which are a risk in terms of SA. Some research consider that CAVs drivers has to remain focused on the road (De Winter et al., 2014), highlighting the need of a conservative position, till the technology and drivers training are not mature enough. A recent US report suggested a similar position and therefore a training need: “drivers need to focus their attention on the roadway at all times but particularly during Advanced Driver-Assistance Systems use” (Manser et al., 2018).

Highlighting the classical automation irony, Louw et al. (2017) suggest two recommendations to go beyond this frustrating conservative position in order to allow NDRT: 1) having a CAV able to get drivers’ attention towards the limitation at least six seconds in advance of an hazard, and 2) having drivers with accurate CAV mental model (our first training challenge). Upcoming WP5 tasks will determine if this conservative position makes sense or if we can go beyond.

In close relation with the SA key impact in CAV driving, we want to make a specific focus on a concept and research stream which showed an increasing interest since last years: the loops in control.

3.3.2.4.2 To be or not to be in the loop?

Regarding CAV driving, being removed of a control loop means that a human share or lose the control, the responsibility of the driving task. Merat highlights that “being out of the loop implies the lack of physical vehicle control and/or a lack of situation monitoring” (Merat et al., 2019).

Merat et al. shared consensual definitions about the different loops possible:

1. In the loop (ITL): In physical control of the vehicle and monitoring the driving situation.
2. On the loop (OTL): Not in physical control of the vehicle but monitoring the driving situation.
3. Out of the loop (OOTL):
   a. Not in physical control of the vehicle, and not monitoring the driving situation,
   b. OR in physical control of the vehicle but not monitoring the driving situation. It's a typical distraction when a driver "looked but failed to see".

As stated by Merat, being in or on the loop does not necessarily mean a driver has to make conscious effort of monitoring, some cognitive processes could be automatic. In case of effort needed, tricks to keep attention awake may be usefully considered in the future training modules.

An observed evidence of a HSS driver being out of the loop (confirmed during post-driving debriefing) is displayed in the Figure 24 below. The driver did not have the control, the HSS does. Her SA was very low, she was distracted, did not pay much attention to the road, and finally crossed her legs making her not capable to promptly and safely takeover if needed.

Figure 24. Subject distracted during an autonomous phase*.*

As confirmed by driving instructors, these different loops are essential to consider in terms of knowledge, skill and behavior. Competence 7 is especially dedicated to it.

As the frontier between competence model and cognitive model is either thin or not existing, SA and loops will also be considered in the cognitive model in Section 3.4.

To summarize Section 3.3 and to have a better understanding of each competence and how they tackle the 4 training challenges above-mentioned, the table 2 is displayed in the following section.

3.3.2.5 The visual display of each competence, per type and related to a training challenge

Table 2 highlights the 20 competences of the CAV competence sub-model and related elements (reference, competence type, etc.) defined in section 3.1.2.

The main column of the table is the competences, displayed in blue. It follows the “blue flow” displayed in Figure 22.

Table 2. Visual display of every competences and miscellaneous elements

Competence number	Competence title	Competence type	Miscellaneous (comment, quote from the literature, tests feedback, Partner's contribution, etc).	References	Training challenges fit 1: mental model 2: optimal workload 3: positive attitudes 4: mastery of procedural skills
1	Knowledge of the capability and competence of the CAV	Declarative knowledge	To avoid complacency and automation bias	Shaw et al. (2020) ; Wickens et al. (2015)	1
2	Knowledge of automation procedures	Declarative knowledge	Avoid automation surprise	Wiener (1989); Hollnagel & Woods, (2005).	1, 2
3	Knowledge of what is the purpose of each technology of the CAV	Declarative knowledge	Autonomous driving features considering system limits and system-controlled responses. Difference of roles between a Driver Driving (DD) and a Driver Monitor (DM)	Endsley (2015)	1, 4
4	Knowledge of the limitations and possible failure of the CAV technologies	Declarative knowledge	Bad connection, dual lane roundabout, crossing a dual lane roundabout. Failure could be related to sensors calibration issues or road conditions.	Liu and Hiraoka (2018)	1, 4
5	Knowledge of the legal constraints/traffic laws related to the driving of the CAV	Declarative knowledge	Similar as a non-CAV legal framework, meaning be able to drive safely	Liu and Hiraoka (2018)	1, 4
6	Supervise the CAV autonomous technology works well	Procedural skill	Attention to the GPS and automation display hints	Liu and Hiraoka (2018)	1,2
7	Knowledge of the practical implications of being In the Loop, On the Loop and Out of The Loop	Declarative knowledge	Automation takes the driver Out of The Loop (low SA). SA is key in preparing to drive following a takeover request. NDRT could serve to illustrate the distraction and highlight the training need.	Merat et al. (2019)	1,2

Competence number	HSS competence title	Competence type	Miscellaneous (comment, quote from the literature, tests feedback, Partner's contribution, etc).	References	Training challenges fit 1: mental model 2: optimal workload 3: positive attitudes 4: mastery of procedural skills
8	Do mirror and blind spot checks when preparing to take over control	Procedural skill	Eye movements are enough to check rear-view and side-mirrors (For the HSS: the push of at least a button is necessary for the side mirrors) Shaw et al (2020). "Look to see where the vehicles and other road users are all around you. How busy is the road, are there vehicles in front of you, behind you, to the right or left of you, in your blind spot? It is important for you to know what else is on the road with you before you take over control of the vehicle movements."	Shaw et al. (2020)	4
9	Do mirror checks during automated driving	Procedural skill	Eye movements are enough to check rear-view and side-mirrors (For the HSS: the push of at least a button is necessary for the side mirrors)	Shaw et al. (2020)	4
10	Do mirror and blind spot checks after resuming manual driving	Procedural skill	Eye movements are enough to check rear-view and side-mirrors (For the HSS: the push of at least a button is necessary for the side mirrors)	Shaw et al. (2020)	4
11	Maintaining fitness to drive during automated driving	Procedural skill	Physical and mental fitness. For Lvl3 CAVs sure. For Lvl4 “Mind off” CAVs (HSS included), still under discussion, especially according to the speed and future event to deal with.	Naujoks et al. (2017)	4

Competence number	HSS competence title	Competence type	Miscellaneous (comment, quote from the literature, tests feedback, Partner's contribution, etc).	References	Training challenges fit 1: mental model 2: optimal workload 3: positive attitudes 4: mastery of procedural skills
12	Check yourself (ready to drive, fit, non-driving task stopped, hands free, comfy chair position and ready to use steering wheel and pedals)	Procedural skill	Reduce distraction (smartphone use, passenger, etc). Establishing take-over readiness Situational readiness	Shaw et al. (2020) ; Naujoks et al. (2017)	2, 3, 4
13	Interrupt NDRT as soon as possible	Procedural skill	Mention to passengers to avoid distracting the driver. Proactively (when able to recognize situations that the HSS may not master) or after a TOR Conservative position related to NDRT. May be updated later.	Naujoks et al. (2017) ; Louw et al. (2017)	2, 3, 4
14	Check for hazards during manual and autonomous mode	Procedural skill	Maintaining situational awareness	Shaw et al. (2020) ; De Winter et al. (2014); Endsley (2015)	4
15	Assess your position (related to the chair and the steering wheel and pedals)	Procedural skill	Follow up action of the Check yourself	Shaw et al. (2020)	4
16	Assess the road	Procedural skill	Follow up action of the Check hazards, mirrors and blindspot. Remain focused on the road. Traffic type (vehicles, pedestrian, etc), Infrastructure (road type, etc), Hazard type and environmental conditions, Signage (road signs including warnings and instruction).	Shaw et al. 2020 ; Casner et al. (2016); Banks and Stanton (2019)	4, 2

Competence number	HSS competence title	Competence type	Miscellaneous (comment, quote from the literature, tests feedback, Partner's contribution, etc).	References	Training challenges fit 1: mental model 2: optimal workload 3: positive attitudes 4: mastery of procedural skills
17	Assess the situation and the next step you will do	Procedural skill	Final assessment before being ready to takeover Shaw et al 2020: "Look to see where you are in comparison to the vehicles around you. Assess how fast the vehicles around you are going, whether they are approaching or moving away from you". Mastering the levels 2 and 3 of Situation Awareness in terms of (2) comprehension of current situation and (3) projection of future status. Level 1 (perception of elements in current situation) is not mandatory to be mastered (defaults values could be used when not known) (Endsley, 2015).	Shaw et al. (2020)	4, 2
18	Takeover control in an appropriate and timely manner (less than 10 seconds)	Procedural skill	Rapid onboarding is needed but the right moment is still under debate. Not too soon to avoid risk of a low SA and not to late (+10 seconds) as the car will automatically park itself.	Casner et al. (2016) ; Louw et al. (2017); Endsley (2015)	4, 2, 3

Competence number	HSS competence title	Competence type	Miscellaneous (comment, quote from the literature, tests feedback, Partner's contribution, etc).	References	Training challenges fit 1: mental model 2: optimal workload 3: positive attitudes 4: mastery of procedural skills
19	Supervise the CAV to be ready to take back control	Procedural skill	Be alert enough to hear the RTI auditory signal and see the visual RTI signal on the GPS and ideally anticipate situations that the HSS cannot handle Unnoticed mode transitions, automation surprise (Sarter and Woods 1995). Situation Awareness (Endsley, 2005) Unnoticed mode transition and mode confusion happened several times during the LIST experiment, even when people admitted that they heard the RTI signal. They did not process it properly (SA level 1 Perception of Elements in current situation) but they failed to reach Level 2 (comprehension of the current situation) negatively impacting their decision and driving performance.	Sarter and Woods (1995); Endsley (2015, 2018)	1, 2, 4
20	Maintaining fitness to drive during automated driving	Procedural skill	For Lvl3, it seems needed, for Lvl4, it needs to be discussed and answered thanks to additional data.	Naujoks et al. (2017)	2, 3, 4

As a corollary of the competence model, the cognitive and affective model is more focused on the driver's internal "black-box".
To facilitate the training module development, two main building best-practices applies to the cognitive model content and structure:

1. Easy to use for the driving instructors in the future training development.
2. Compromise between parsimony and exhaustivity.

3.4 The CAV cognitive and affective model

A cognitive model is a "general framework for specifying computational behavioural models of human cognitive performance" (Salvucci, 2006). It can detail the abilities and constraints of a human (related to memory, perception, visual and motor abilities, etc.).
For WP5 objective, the CAV cognitive and affective model is a description of the key cognitive and affective states about a CAV driving task. As in competence models, top or ideal drivers are modelled, meaning we should display the ideal combination of cognitive and affective states that contribute to drive safely a CAV.

Like the competence model, personal, environmental factors and moderators are displayed and might be updated later thanks to the final data analysis results.
As the CAV cognitive and affective model is simpler than the CAV competence model, there will be no specific table or multiple categories description: every element of the cognitive/affective model are considered in the two upcoming sub-sections – 3.4.1 and 3.4.2 - including references, test's feedbacks, etc.

The CAV cognitive and affective instance or model is displayed in Figure 25.

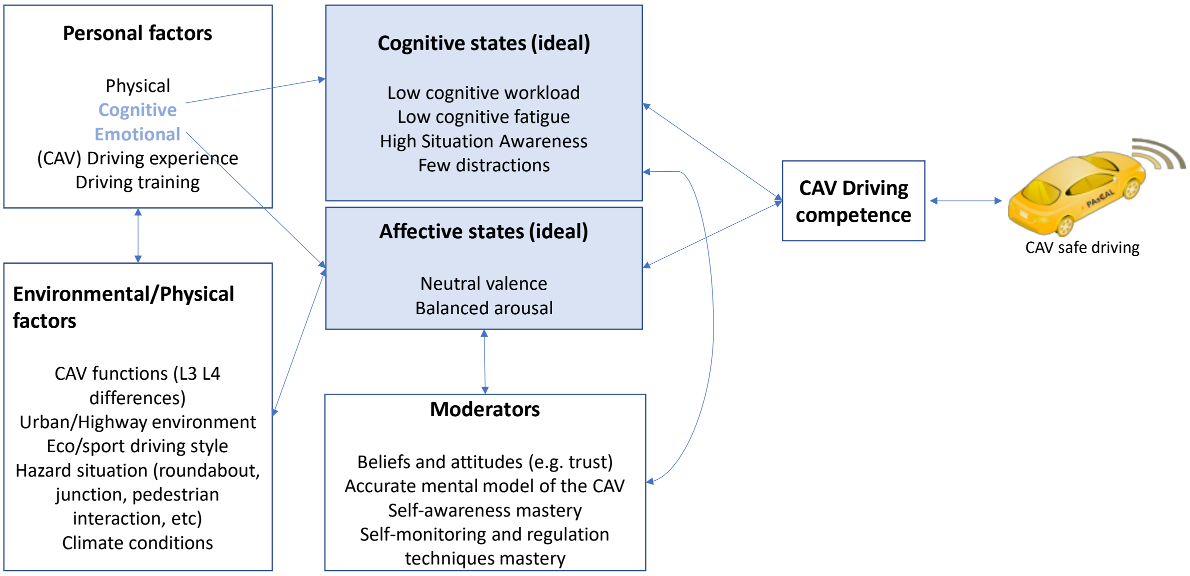

Figure 25. The CAV cognitive and affective model.

The cognitive states component will now be presented. Then the affective states component will be detailed.

3.4.1 Cognitive states

As shown in the SUaaVE sister project (Iranzo et al., 2019), multiple cognitive states can be considered when dealing with CAV driving. As for our competence model, again, exhaustivity can be counterproductive. Therefore, we selected only five main cognitive states to consider: cognitive workload, cognitive fatigue, SA, vigilance, and distraction.

As described in Section 3.3.2 of the competence model, **cognitive workload** and **cognitive fatigue** are key to safe driving.
The cognitive fatigue concept is a corollary to the Maintaining fitness to drive during automated driving competence (see number 11 in the competence model Table 2).
Even if the automation mode of a CAV can increase the cognitive resources of a driver (Shaw et al. 2020), new events or situations (e.g. mode transition, NDRT) could at the same time lower the level of available cognitive resources. As HMI application (e.g. using voice, music,

temperature, light) are promising solution to alert the driver and help him to regulate its cognitive resources state, the Pascal' project partners may also act on cognitive fatigue through training.

Situation Awareness (and related loops concepts), as already presented in the competence section, is a key state to safe driving and is in both competence and cognitive models. See section 3.3.4.1 for details.

Vigilance
A low vigilance increases the risk of accident and therefore a high level of vigilance should be targeted and facilitated by any CAV training.
As known for years, low vigilance is a problematic state when a driver must perform long driving tasks (aggravated on Highway), with monotonous conditions. Several LIST experiment subjects confirmed loss of vigilance during urban sessions. Even sleepiness states have been observed during a LIST test. Related to SA, drivers tend to transform into passengers after automation periods, with low vigilance and attention. Low vigilance reduce the chance of being proactive rather than reactive (Endsley, 2019).
HMI application and driving school training are means to mitigate the process of loss of vigilance (Gonçalves et al., 2017).
Vigilance is also considered in the following Emotional states section.

Distraction
With the increasing capacities of autonomous vehicles, distraction is at the same time a gain (e.g. leisure, time saved) and a risk (e.g. attention issues) for the drivers.
Even if distractions were limited during the LIST tests (no formal NDRT, see Hergeth et al., 2016 for a review), few LIST subjects were distracted and failed to respect speed limits or to position the CAV at a proper place. A strong investigation on bigger data sets will be needed in the upcoming tasks to determine if, with trained drivers, we will be able to distinguish safe and risky distraction:

- In terms of distraction type (e.g. talk with passenger, entertainment task)
- and in terms of distraction intensity, duration, etc.

Automation levels (3 and 4), according to the specific features of the CAV, will also need careful consideration as mentioned previously in the Competence model section 3.1.2.

3.4.2Emotional states

As discussed in the SUaaVE sister project (Iranzo et al., 2019), the driver's emotional state should also play a crucial role for CAV driving. Research indicates that different emotions exert different influences on driving behaviour with traditional vehicles (for a recent review, see Braun et al., 2022). Although specific emotions such as anger, fear, happiness, or relief can be regarded as distinct categories that elicit a certain response, another very common and fruitful approach is to an describe an emotion on the two dimensions valence and arousal.

Both valence and arousal can be regarded as continuous scales. Valence refers the pleasantness that is evoked by the emotion, ranging from very unpleasant (negative) to very pleasant (positive). Arousal refers to the evoked activation, ranging from very passive (low) to very active (high).

Thus, for the cognitive and affective model, we will take this differentiation between valence and arousal into account and separately discuss the expected impact of these dimensions on CAV driving. Moreover, we highlight some specific emotions that have been shown to influence driving behaviour with traditional vehicles and should also be relevant for CAVs.

3.4.2.1Valence

A vast majority of research on affective states focused on the valence-dimension. Pertinent to the present model, research assesses effects of valence on a) motivation, b) attitudes, and c) cognitive functioning and processing styles.

With regard to motivation, positive states – as might be expected – have been shown to be engaging. Thus, a happy driver is the one who will keep using the given driving mode. As for Level 3, this indicates that the experience needs to be pleasant so that the driver does not switch back to old modes. Pleasant states will finally translate into more positive attitudes towards the driving mode and associated features. This overall acceptance is a key determinant for drivers to learn the new modes, but also to cope with setbacks.

Regarding cognitive functioning, however, positive states are not necessarily desirable, as they are detrimental to deep cognitive processing. A plethora of mood studies indicates that positive mood reduces vigilance and prevents from processing information in an analytic manner. Instead, positive mood has been shown to facilitate automatic processing styles and the reliance on routines. After all, positive affective states are predicted to decrease reactivity in hazardous situations, e.g., if the driver must takeover. This is especially likely for novices (i.e., untrained users of L3-vehicles) who do not have routines they can rely on in critical situations. It is therefore mandatory to consider affective states in trainings for CAV users.

For one thing, drivers need to learn to monitor their affect (which might not stem from the pleasant driving experience per se, but secondary activity such as entertainment use). Second, they need to learn to automatize the L3-usage (from using features or not using them when required) so they can take over even in positive states (which will be the default rather than the exception).

After all, positive mood is associated with a more holistic, „top-down“ information processing, while negative mood leads to a more systematic, „bottom up“ information processing (Bless et al., 1992) and less focused attention (Knörzer et al., 2016). Thus, one can expect a detrimental effect of positive mood on tasks that require vigilance and detailed information analysis, such as hazard perception. However, since positive mood also promotes a more schematic information processing and the reliance on habits, positive mood should facilitate the intuitive use of automated procedural skills, such as assessing the road, doing mirror checks, etc.

This highlights the importance of training for procedural skills (the fourth competence training challenge detailed in Section 3.3.4).

The goal should be to automate important routines needed for safe automated driving to an extent, that they will also be performed adequately by persons in suboptimal affective and cognitive states, such as happy but incautious drivers.

Neutral valence is targeted.

3.4.2.2Arousal

Research on the arousal-dimension can best be summarized by the Yerkes-Dodson law (see Figure 27).

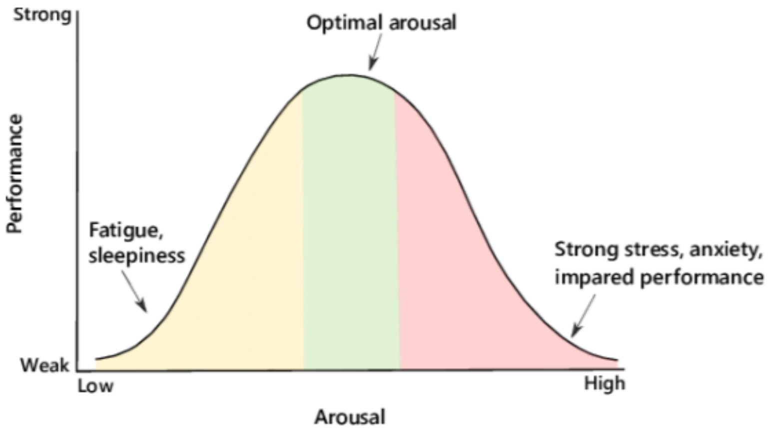

Figure 26. The Yerkes-Dodson law of optimal (Gressenbuch & Bergemann, 2019).

The best cognitive functioning and task performance is achieved at medium levels of arousals, while both very low and very high levels of arousals are clearly detrimental to performance. Hence, fatigue and sleepiness on the one hand and high stress and anxiety on the other hand are bad states for save driving (Gressenbuch & Bergemann, 2019). However, detrimental effects of arousal are not limited to negative emotions like stress or anxiety. Pleasant arousal, such as in the form of elatedness or excitement can also lead to suboptimal performance because after all, both positive and negative emotions lead to the activation of irrelevant thoughts and posit an irrelevant cognitive load (Fraser et al., 2012; Seibert & Ellis, 1991).

Thus, for an optimal driving performance, a calm and relaxed, but not fatigue state of mind, is desirable. Unexperienced users of CAVs or people with dispositional anxiety might need some time and support to develop trust in automated vehicles and overcome stress or anxiety which would consume cognitive resources needed for safe driving. More carefree people might need to be reminded of the autonomous system’s limitations to prevent overreliance on the system’s capabilities (Saffarian et al., 2012). Drivers who think that they are not needed at all might excessively engage in NDRTs which makes it hard to get into the loop again. Especially experienced drivers might get bored or overestimate their own skills, e.g., regarding their take over time (Gold et al., 2013) once they do not need to perform all driving actions by themselves.

They should be trained to estimate take over time realistically and to maintain proper levels of vigilance and arousal.

Balanced arousal is targeted.

3.4.2.3Specific emotions

More recently, researchers have tried to disentangle the impact of different emotions on driving behaviour, even if they belong on the same valence or arousal dimension. For instance, several studies have been shown that although anger and fear are both negative emotions that increase arousal, anger clearly leads to more driving errors than fear (Jeon et al., 2011, 2014). Moreover, anger reduces risk perception while fear increases it (Lu et al., 2013). However, risk perception that is induced by fear seems to be more easily targeted by emotion regulation strategies such as reappraisal of along the dimensions of certainty (e.g., “I will be safe.”), control (e.g., “I am capable of driving safe.”) or responsibility (e.g., “I am responsible for my safety”).

Hence, an angry driver is not the same as a fearful driver and emotions might need to be treated diversely to assure the best driving performance. Fear that was induced by a lack of experience with autonomous vehicles or low amounts of trust in new technologies might be effectively reduced by cognitive reappraisal strategies (e.g., reassuring that the technology has been tested to be traffic safe). On the other hand, anger that was induced by someone else’s traffic behaviour might need detection and additional external regulation through the human machine interface. For example, the autonomous system could identify the emotion, alert the driver to maintain proper risk perception and maybe even start to play relaxing music.

As a conclusive paragraph for the CAV cognitive and affective model, we will briefly present means to help a driver reach ideal cognitive and affective states for a safe driving. As it will be part of the next WP5 deliverable, only few references will be suggested in this document as recommendations and references to consider.

Like the importance of competence self-assessment, cognitive and affective states awareness is a key capability for safe driving. Several studies highlight the importance of emotion awareness and emotion regulation.

In addition to training modules on competences, emotion regulation techniques could be also considered as WP5 training outputs (Hancock et al., 2012; Naragon-Gainey et al., 2017; Trogolo et al., 2014). For example, as previously mentioned, a relaxing music could mitigate negative emotions (Fairclough et al., 2014).

If the WP5 outputs are not to provide a system able to assess and regulate the emotional state of the driver (as done in the SUaaVE project), music, for example, might still be an efficient and cost-effective regulation technique to consider in the upcoming training.

4 Conclusion

The definition of the requirements of road driving education and training in a CAV environment was the prerequisite of WP5 work. This task fell on all WP5 partners but in particular on the two driving schools' partners, ACI and RDS, both state-of-the-art driving schools in their respective countries. Their starting points were, quite obviously, their experience and the respective governmental directives on driving training, which turned out to be rather complementary in their substance if not in form or, as obvious, in language.

On this basis, the specificities concerning the CAV environment had to be inserted. This proved to be challenging, because of the ongoing debate on the specific features characterizing L3 and L4 of automation which, at this moment, still prevents from knowing exactly how a vehicle behaves, which road situations it is able to master autonomously.

However, this point is particularly relevant, because the moment in which the vehicle asks the driver to take back control or when the driver wants to regain control because he/she feels the vehicle is not able to handle the situation correctly will most probably be the most critical moments in the mixed (partly autonomous, partly traditional) traffic situation of the coming years.

Hence, it is the moment which, from a driving training point of view, needs to be studied and examined. It may also influence, on a general basis, the degree of acceptance of CAVs.

Therefore, WP5 decided that the situations designed for testing had to consider behaviours/reactions to specific difficulties in order to obtain general information, valid independently from the single countries' specific rules. Hence the choice for two environments, Urban and Highway, which cover most traffic situations and the design of specific critical situation, typical of each scenario, which may be problematic for L3 and L4 CAVs.

The process followed to build the competence and cognitive and affective models started with a literature review, reinforced with feedbacks and exchange sessions between the WP5 partners.
This work resulted to the proposal of two hypothetical models: one dedicated to the competence aspects and one to the cognitive and affective aspects related to CAV drivers. These models will be useful to

support the definition of new training modules planned in the next steps of WP5.

As shown in the lower part of the models building process (Figure 12), let’s underline that iterative feedback loops will make it possible to update, enrich and validate these models as more data related to the test sessions conducted by the WP4 and WP5 partners will be collected and analysed.

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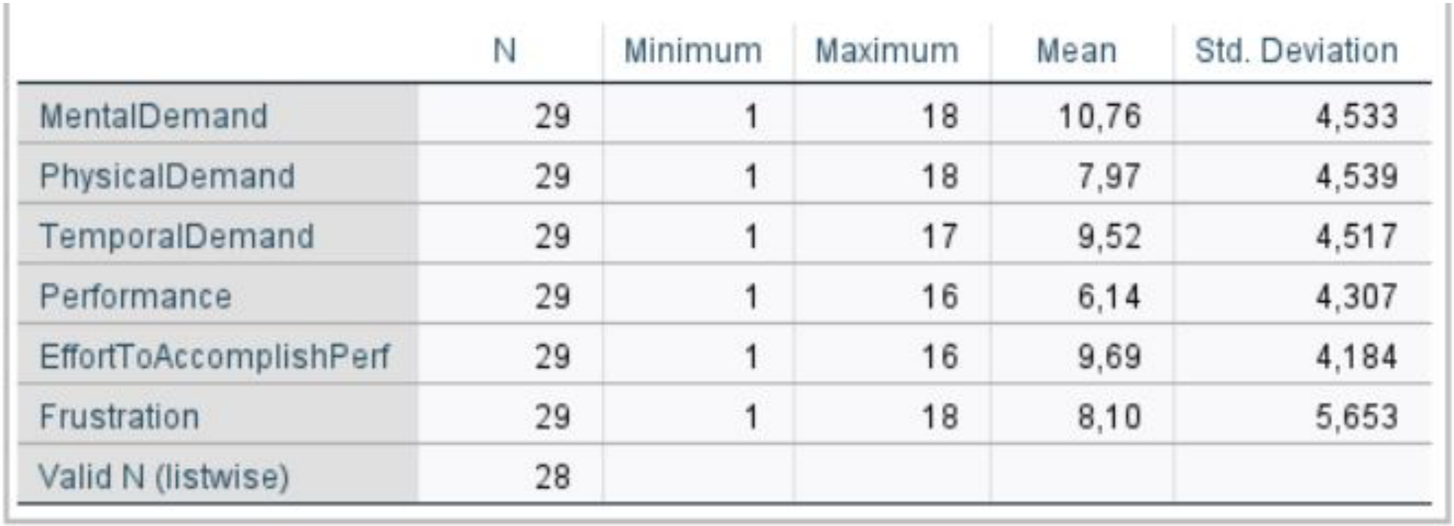
6 Annexes

6.1 Annex 1. Results of the NASA TLX questionnaire – LIST experiment

Due to the current small sample (which will increase during the following weeks), these preliminary results must be considered with caution and will be updated if needed.

Thanks to 8 LIST experiment's subjects, 29 Nasa TLX questionnaires have been collected and analysed (see table 3).

Table 3. *Descriptive statistics of the Nasa TLX questionnaire*



	N	Minimum	Maximum	Mean	Std. Deviation
MentalDemand	29	1	18	10,76	4,533
PhysicalDemand	29	1	18	7,97	4,539
TemporalDemand	29	1	17	9,52	4,517
Performance	29	1	16	6,14	4,307
EffortToAccomplishPerf	29	1	16	9,69	4,184
Frustration	29	1	18	8,10	5,653
Valid N (listwise)	28				

As displayed in Table 4 below, only few of them (trainee 1, 2 and 21) did the full experiment scheme, meaning 4 driving sessions.

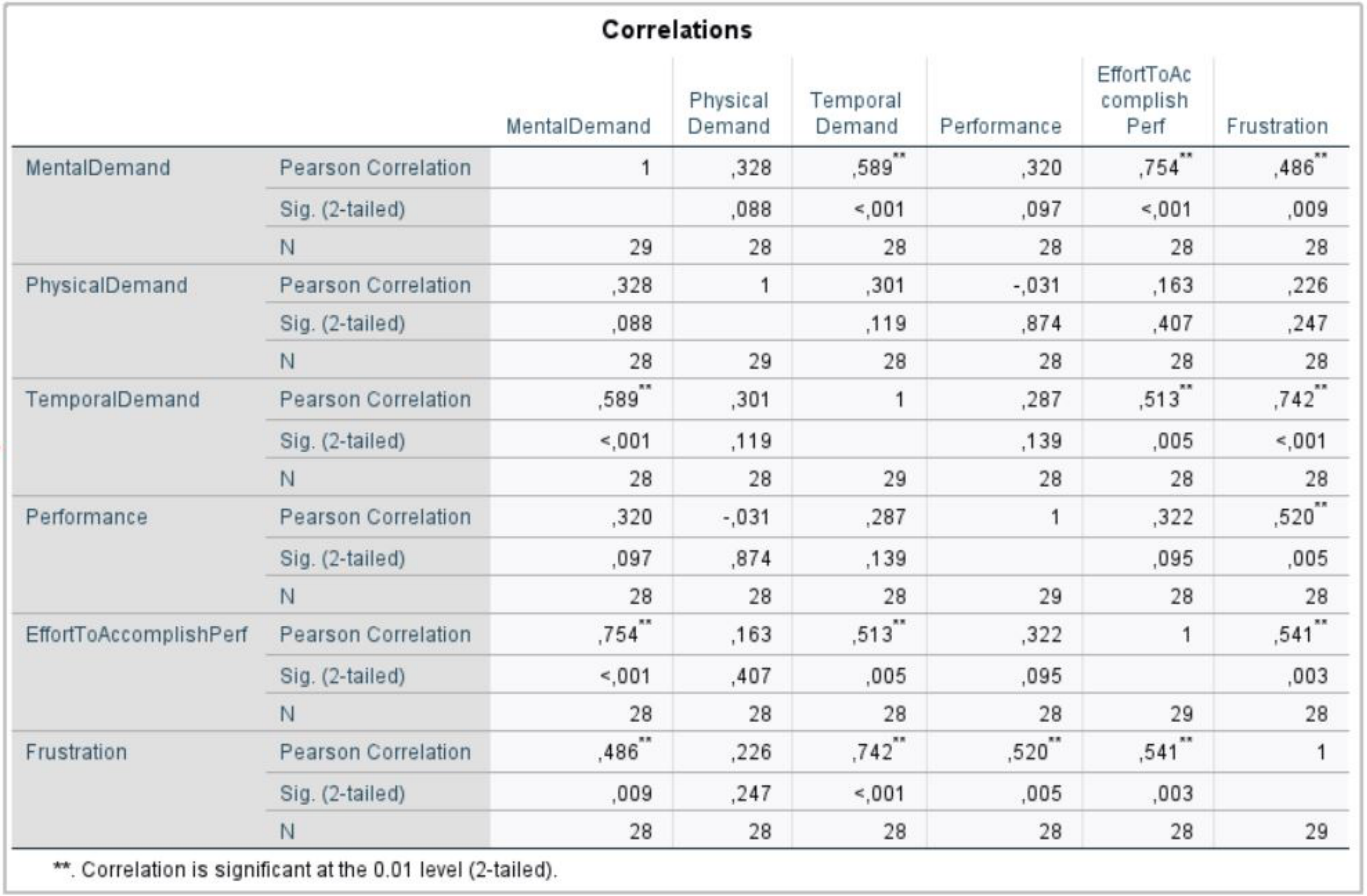
Table 4. *Nasa TLX and affective results of the LIST experiment*

Anonymous trainee id	**Session (1 to 4)**	**NASA TLX results – From 1 to 21**					
		Mental demand Low-High	Physical demand Low-High	Temporal demand Low-High	Performance Perfect-Failure	Effort to accomplish performance Low-High	Frustration Low-High
5	1	15	17	17	4	10	11
	2	11	18	11	5	11	17
	3	10	14	11	3	5	4
10	1	13	11	4	5	15	2
	2	15	12	5	4	11	5
	3	8	10	4	12	6	4
16	1	18	4	17	16	15	18
	2	16	10	16	14	15	16
	3	15	12	16	9	13	15
1	1	17	6	10	8	16	15

	2	7	3	10	6	13	5
	3	13	3	12	5	14	14
	4	13	6	6	10	6	7
7	1	6	5	6	6	8	5
	2	3	5	3	5	4	3
	3	2	2	2	6	2	1
3	1	14	6	11	11	11	6
	2	10	11	11	16	12	15
	4	10	4	11	6	11	11
2	1	15	9	8	2	13	2
	2	9	5	6	2	7	7
	3	14	5	10	2	13	3
	4	8	4	8	1	5	3
21	1	8	12	11	2	11	12
	2	11	10	11	3	6	4
	3	10	12	10	3	10	3
	4	5	3	11	3	5	9

Bivariate correlation

Table 5. *Correlation between Nasa TLX sub-scales*



Correlations

		MentalDemand	Physical Demand	Temporal Demand	Performance	EffortToAccomplish Perf	Frustration
MentalDemand	Pearson Correlation	1	,328	,589**	,320	,754**	,486**
	Sig. (2-tailed)		,088	<,001	,097	<,001	,009
	N	29	28	28	28	28	28
PhysicalDemand	Pearson Correlation	,328	1	,301	-,031	,163	,226
	Sig. (2-tailed)	,088		,119	,874	,407	,247
	N	28	29	28	28	28	28
TemporalDemand	Pearson Correlation	,589**	,301	1	,287	,513**	,742**
	Sig. (2-tailed)	<,001	,119		,139	,005	<,001
	N	28	28	29	28	28	28
Performance	Pearson Correlation	,320	-,031	,287	1	,322	,520**
	Sig. (2-tailed)	,097	,874	,139		,095	,005
	N	28	28	28	29	28	28
EffortToAccomplishPerf	Pearson Correlation	,754**	,163	,513**	,322	1	,541**
	Sig. (2-tailed)	<,001	,407	,005	,095		,003
	N	28	28	28	28	29	28
Frustration	Pearson Correlation	,486**	,226	,742**	,520**	,541**	1
	Sig. (2-tailed)	,009	,247	<,001	,005	,003	
	N	28	28	28	28	28	29

**. Correlation is significant at the 0.01 level (2-tailed).

6.2 Annex 2. WP4 and T5.3 experiments overview

The test consists in four visits of the user.

Participant Group Management
There are two groups in the study, the only change this has is the order in which they experience tracks in the second and third phases.

Within subjects study, aim is to look at acceptance and change in cognitive load over time. Not to compare group A or group B, they are only set up like that to avoid ordering effects. Likely to be at most 30 participants. The number 0,1,2 indicates the route that should be chosen.

	Group A	**Group B**
Training phase	Path 0 (15 minutes driving) Low Traffic (20)	0 (15 minutes driving) Low Traffic (20)
First Test Environment	Path 1 (High traffic 60)	Path 1 (low traffic 20)
Second Experience	Path 2 (low traffic 20)	Path 2 (high traffic 60)
Third Experience	Path 2 (high traffic 60)	Path 2 (low traffic 20)
Final Test Environment	Path 1 (low traffic 20)	Path 1 (high traffic 60)

Traffic settings options: low (20) or high (60).

Visit	duration	Preliminary		Simulator scenario	Rep grid	Online questionnaires	Nasa TLX questionnaire	Evaluator support
1	2 hours	Consent form	Explain simulator	Group A or Group B also see week/experience above	X	X	x	First visit observation grid (during training)
2	1 hour					X	X	
3	1 hour					X	X	
4	2 hours				X	X	X	Final Observation Grid during trial

The duration includes driving time, questionnaires and in the first and last phases the rep grids step. Note that the settings used in the simulator for each group will vary in each round depending on the group the participant is assigned to (See, participant group structure document on SHP).

First Visit

Important: Explain to the participant the overall purpose of the trial, their role in it, and their rights.

Overall purpose of the trial

1. Provide the participant with a copy of the study letter, they may also have been sent this prior to arriving. If they have not read through it already, then ask them to do so.
2. Explain the purpose is to test your behavior in and opinions of connected autonomous vehicles.
3. Explain it is part of the PAsCAL project
4. Explain that we are assessing the system more than how you perform in it. Our interest is in how we can improve such vehicles in future.
5. Explain that as this is the first session, you will take part in a 15-minute training section, then you will take part in a **30-minute** driving trial.
6. Explain that the trial will be followed with some questionnaire and a short semi-structured interview.
7. Allow them to ask any questions, but you should not discuss exactly what data will be collected beyond saying it is basic information such as vehicle speed and position. The same applies to questionnaires, we don’t want them to behave in any certain ways.

Rights and Consent

1. Inform them of their rights, including the right to withdraw
2. Explain to them that they need to give informed consent, and ask them to sign the document

Provide them with the informed consent document and study information sheet. Ensure they sign it and that you also sign a copy. They should be given one copy and we retain one.

Using the Simulator – Training

Simulator settings:
Path 0

1. Urban environment
2. Mode eco
3. 20 vehicles (traffic density setting: low)

Ensure these are set PRIOR to starting.

<u>Show the participant the steering wheel and pedal information sheet</u>

1. Explain to them the basic controls of the vehicle before starting the simulator. You can show them the piece of paper with the info on it.
2. Explain that we do not use the data collected in the simulator
3. Explain that during this training step they can ask whatever questions they want.
4. Explain the driving session will last 15 minutes, for 5 minutes they will be in manual mode
5. Show them how to login, explain it.
6. Now start the training environment (route 3), making sure that it is in eco mode and traffic is set to 20.
7. If offered to do so, they should complete the profile questionnaire.
8. Remind them of the mode changes, autonomous to manual, and manual to autonomous and how they work, including audio tones and how to resume control
9. Explain the GPS navigation how the routes approach in autonomous mode works.
10. Now they can start and learn to drive.
11. If they make some obvious errors, you can intervene and tell them how to correct it.
12. They can talk aloud and ask questions while driving.
13. They should stop after 15 minutes of driving has been completed (press escape)

During this phase please complete the First observation sheet section for the training phase, noting down any problems they encounter. Any other interesting observations should also be noted (complaint, remark, distraction, which might be helpful to consider acceptance, competence, design protocol, etc).

They can complete their profile questionnaire but should not complete the other questionnaires e.g. NASA TLX or general questionnaire. These should be completed after the testing session below.

First Testing Session

1. Remind the participant that this is now the first testing session.
2. Check the vehicle settings are correct for this participant.
3. Remind them that is data from this part which will be used and that the future questionnaires relate only to this section, not the training part that they have just completed.
4. Remind them that you will not intervene during this part and that they should try to not ask for help unless they are totally stuck. Also, that we will not intervene unless there is an obvious problem, including a system fault.
5. Complete the rep grids study
6. After completing the trial, they will be prompted to complete the questionnaire, they can ask questions for clarification at this point. However, you should not guide them in how to answer.

Debriefing

1. Following the study, do a short debrief. Reminding them of the purpose of the study, also their rights and ask for any feedback relating to procedures etc. Please take notes of this.

Second and Third Visits

The participant is NOT observed during these sessions, and the evaluator should not sit with the participant. However, the evaluator should be nearby to answer questions.

1. Ensure the participant has logged in
2. Set them up with the correct route including traffic density
3. Remind them of the trial and that this time you will not be present, but the same information is being collected.
4. Remind them that they will be asked to complete some questionnaires at the end

There is no rep grids phase for these trials.

Fourth and Final Visit

Overall purpose of the trial

Explain the purpose is to test your behaviour in and opinions of connected autonomous vehicles.

- Explain it is part of the PASCAL project
- Explain we are assessing the system more than how you perform in it. Our interest is in how we can improve such vehicles in future.
- Explain that today they will take part in a **30-minute** drive (approx.) as they did in the previous two sessions.
- Explain that the trial will be followed with some questionnaire and a short semi-structured interview (rep grids). Similar to the one they did at the start.
- Allow them to ask any questions, but you should not discuss exactly what data will be collected beyond saying it is basic information such as vehicle speed and position. The same applies to questionnaires, we don't want them to behave in any certain ways.

Rights and Consent

- Inform them of their rights, including the right to withdraw

Final Testing Session

- Check the vehicle settings are correct for this participant including route and traffic density
- Remind them that is data from this part which will be used and that the future questionnaires relate only to this section, not the training part that they have just completed.
- Remind them that you will not intervene during this part and that they should try to not ask for help unless they are totally stuck. Also, that we will not intervene unless there is an obvious problem, including a system fault.
- Complete the rep grids study
- After completing the trial, they will be prompted to complete the questionnaire, they can ask questions for clarification at this point. However, you should not guide them in how to answer.

Debriefing

- Following the study, do a short debrief. Reminding them of the purpose of the study, also their rights and ask for any feedback relating to procedures etc.
- At this point you can give them full information about the study, including what was collected, why and what we are exploring. However, they should be asked not to share this information with anyone.
- Remind them again of any data protection and ethical rights
- Please take notes of this.

6.3 Annex 3. First session Observation sheet

Participant ID:
Time:
Date:

This document is to be used to record information relating to the participants during their first visit.

In addition to validate or note a “completed” step, you can also describe faults when it happens. It will ease a lot the WP5 deliverables (competence modelling but also training building) which need WP4 outputs.

Use of Simulator

Step	Completed	Notes
Explanation of login procedure		
Explanation of car controls (including joystick to check mirrors and circle/square buttons to quickly turn head to check mirrors)		
Explanation of button controls		
Explanation of safety implications of a delayed response in resuming control over automated mode		
Starting the simulator		

Skills Check - During Training Phase

Manual Driving

Step	Completed	Notes
Safe and appropriate acceleration		
Steering controls		
Breaking		
Using indicators (blinkers) > *one of the key controls that is forgotten during manual mode. Keep repeating it is needed.*		
Using mirrors (including the hidden right mirror by using joystick or buttons) > *one of the key controls that is usually forgotten during manual mode. Keep repeating it is needed.*		

Respecting priorities (intersection, roundabout, etc.)		
Approaching all crossroads using the MSPSL routine (Mirrors, Signal, Position, Speed, Look) **Mirror, signal, manoeuvre (MSM)** M - Check in the mirror to assess the speed and position of the vehicles behind S - Signal clearly and in good time M - Manoeuvre - use PSL **Position, speed, look (PSL)** P - Position your vehicle correctly and in good time. Early positioning lets other road users know what you are going to do S - Adjust your speed as necessary L - Look for other traffic when you reach a point from which you can see. Access the situation. Decide to go or wait. Act accordingly		
Safe and timely resumption of control from autonomous mode (when drivers must take over manual control and handle a situation)		
Any other behaviour/action you consider useful to note in terms of acceptance, competence to master/train		

Automated Driving

Step	Completed	Notes
Monitoring of the road and driving environment (keep focused even if they are not actively steering the car)		
Monitoring of the status of the automated mode (On/Off) and that it works properly		
Knowledge of what aspects of the driving tasks is and is not automating		
Taking over (back to manual mode) in a smooth way (e.g., stable use of the brake or acceleration pedals, keep the vehicle well positioned on the road)		

Skills check - During Test Phase

Manual Driving

Step	Completed	Notes
Safe and appropriate acceleration		
Steering controls		
Breaking		
Using indicators (blinkers)		
Using mirrors		
Respecting priorities (junction, roundabout, etc.)		
Approaching all crossroads using the MSPSL routine (Mirrors, Signal, Position, Speed, Look) Mirror, signal, manoeuvre (MSM) M - Check in the mirror to assess the speed and position of the vehicles behind S - Signal clearly and in good time M - Manoeuvre - use PSL Position, speed, look (PSL) P - Position your vehicle correctly and in good time. Early positioning lets other road users know what you are going to do S - Adjust your speed as necessary L - Look for other traffic when you reach a point from which you can see. Access the situation. Decide to go or wait. Act accordingly		
Safe and timely resumption of control from autonomous mode (when drivers must take over manual control and handle a situation)		
Any other behaviour/action you consider useful to note in terms of acceptance, competence to master/train		

Test phase: automated Driving

Step	Completed	Notes
Monitoring of the road and driving environment (keep focused even if they are not actively steering the car)		
Monitoring of the status of the automated mode (On/Off) and that it works properly		
Knowledge of what aspects of the driving tasks is and is not automating		
Taking over (back to manual mode) in a smooth way (e.g., stable use of the brake or acceleration pedals, keep the vehicle well positioned on the road)		

Cognitive event	Observed (Yes/No)	Notes (e.g. Frequency and intensity of the cognitive event, quotes of the driver speaking out loud, comments about the situation and action related to the cognitive event)
Overtaxation (“It takes too much of my capacity”)		
Undertaxation (“I want to do something else”)		
Frustration		
Helplessness, loss of control		
Surprise		
Overestimating CAV’s, overreliance (“I am not needed at all”)		
Overestimating own skills *(e.g. take-over time and quality)*		
Mode confusion *(autonomous and*		

not autonomous mode activated)		
Another cognitive event you consider useful		

Affective element	Observed (Yes or No)	Notes (e.g. Frequency and intensity of the affect, quotes of the driver speaking out loud, comments about the situation and action related to the affect)
Stress (overreaction, loosing head, etc.)		
Anger (impaired risk perception, rule violations, aggressive driving, etc.)		
Boredom (lack of vigilance, playful behavior)		
Ease/pleasure/happiness (superficial information processing, low vigilance, and awareness)		
Contempt, complacency (withdrawal of actions)		
Another affective event you consider useful		

--- End of the document ---

PAsCAL
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of Connected & Autonomous vehicles