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Does the learner driver remain in control of assistance systems?

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Abstract

Automated systems (like ADAS) put new and additional requirements at the driver for supervising safe system operations. Despite ADAS' potential advantages for traffic safety and efficiency, assessment of such requirements is not included in driver licensing today. Based on a narrative review of aspects that define preferred driving behaviour, this research collected relevant behavioural aspects for the assessment of a learner driver's supervisory role. It was acknowledged that ADAS causes both interruptions and temporarily rises in task-level required from drivers. An important assessment will therefore be whether the learner driver is capable of switching between the required tasks levels, while safeguarding correct anticipation and the interests of other road users. The assessment should also include correct application of system knowledge. These results set an important step in exploring how driver training and testing should increase drivers' ability to correctly work with automated driving systems and take full advantage of them.

Keywords:

Automated driving, Driving examination, Driver training

1. Introduction

The introduction of automated systems in the car does not only raise vehicles' complexity, it also has a large impact on required drivers' capabilities. Contrary to general thoughts, automated driving may not necessarily make the whole driving task easier. It will only do within the boundary conditions suitable for automation. Then, the driving tasks and responsibilities of the driver will change from actively operating the vehicle to being a supervisor with the responsibility for safe vehicle operation. To fulfil these tasks, necessary competencies of the user of a self-driving car are likely to change tremendously in (near) future compared to driving proficiency as required today. However, assessment of required competences of a learner driver to act as a supervisor of system controlled vehicle operation is not included in driver licensing. Therefore, this paper explores an approach to include the appraisal of learner drivers' competencies to supervise system controlled functions. The importance of such appraisal grows, while the demand for safe system operation raises due to the expected steep take-rate of

new support functions. This is illustrated by a proposal from the EU-council to include assistance systems, like Autonomous Emergency Braking (AEB), Lane Keeping Assist (LKA) and Intelligent Speed Assistance (ISA), as mandatory equipment for new vehicles from 2022 onwards [1]. It marks the growing importance of system supervision and subsequently changing role of the driver.

Aim and scope

This research constitutes a first step towards answering: *How to assess a learner driver's role as supervisor and responsible operator of system-controlled vehicle functions?*

System-controlled functions, and "automation" in general, may have different configurations and applications. For practical reason we started our appraisal of learner drivers' competencies in system-supervision for a specific use case, i.e.: highway cruising with Adaptive Cruise Control (ACC). Furthermore, the intention was that the assessment of learner drivers' role as supervisor and responsible system operator would be complementary to existing procedures of driving examination, for which we have taken the Dutch situation as a reference. Furthermore, we primarily focus on examination for license category B (passenger vehicles).

Background and approach

This study is covered in a larger project called Prautocol, initiated by HAN Automotive Research in the Netherlands. Prautocol aims at developing a framework for certification of both vehicle and driver of autonomous technology in order to advise on driving permission procedures. Based on literature and feedback from driving instructors we scoped out general and theoretical considerations for acquiring driving proficiency. These aspects are covered in Chapter 3. Chapter 4 explains the approach that is applied in Chapter 5 to determine those aspects relevant for assessment of the driver's additional responsibility for system supervision (while focussed on highway cruising with ACC). It also reflects on the validity to generalize results for supervision of assistance systems in general. Finally, Chapter 6 provides recommendations for further research and a final conclusion. To start with, Chapter 2 will briefly excurse why the changing driver's role set new demands for driving examination.

2. Gap between driver's responsibility and driver training

Human responsibility for safe vehicle operation

Basic building blocks for automation of longitudinal and lateral control have been available for years in advanced driver assistance systems (ADAS). However, automated driving is not able to substitute seamlessly for a human driver. This is because safe implementation of complete automation requires highly reliable machine-based sensing of the environment in combination with faultless understanding of its environment and decision-making. Due to the highly complex traffic circumstances, current systems do not meet these requirements [2], [3] – leaving an important task at the driver to supervise safe system operation. Implementation of automated driving is therefore targeted from levels of so

called ‘semi’ or ‘partial’ automation to ‘high’ automation – but not (yet) full automation [4], [5]. This implementation means that the driver remains responsible.

Demanding supervisory role

For the foreseeable future, automated vehicle technologies, will continue to rely on a “responsible” driver to oversee the technology, capable of resuming control and having the foresight to make many (yet to be defined) strategic operational decisions. However, this responsibility in combination with reduced involvement in the control task causes a changed, yet difficult, role for the driver. That is: The driver’s task changes to a supervisory role during automation with the necessity to retake control during transition from automation to self-driving [6]. However, this new role is not something humans are good at. Supervision, for instance, is accompanied with low vigilance and behavioural adaptation [7], causing e.g. slower reaction times, misinterpretation [8], [9] or skill degradation [10]. Intervention is impaired by reduced Situation Awareness and increased Workload. Studies revealed that it takes considerable time to take back control when not being actively involved in the driving task [11], [12].

To summarize: While relying on a responsible driver, the application of driving automation creates a gap between drivers’ responsibilities and human capabilities for safe vehicle operation. This gap is not being addressed by current practises of driver licensing. The urgency to reduce this gap grows now that EU policy makers propose some assistance systems (like AEB and LKA) to be mandatory equipment on new vehicles [1].

3. Theoretical considerations on acquisition of driving skills

Driving is a multi-faceted task that complicates definition of normative assessment criteria. The assessment of driving proficiency is therefore generally based on evaluating learner driver’s behaviour within situations that are representative for the complexity of the driving task [6], [13]. This chapter provides theoretical knowledge that describes human abilities to acquire driving skills as well as a theoretical framework to describe the driving task. This knowledge will be used in following chapters to define and explain those aspects specifically relevant for the assessment of driver’s supervisory role.

Bloom’s learning objectives

Gaining driving proficiency is a learning process. Learning objectives are largely influenced by the nature and complexity of what needs to be learned. A generally accepted hierarchy of learning objectives is provided by Bloom [14] and – ordered by raising complexity – consists of: (i) *Remembering*; (ii) *Understanding*; (iii) *Applying*; (iv) *Evaluating*; (v) *Creating*. For each of these levels assessment criteria may be defined. An example of a learning objective at the Remembering level is to know traffic rules by heart.

Levels of driving proficiency

The Dutch handbook for driving instructors advices to assess learner drivers' proficiency on 4 levels, i.e.: *Perception* ("waarnemen"); *Understanding* ("begrijpen"); *Ability* to act ("kunnen") and *Motivation* to act ("willen"). Basically these levels are comparable to Bloom's levels of learning objectives (i) *Remembering* till (iv) *Evaluating*. The higher levels are generally required in more complex driving situations. A driving theory test especially addresses Bloom's learning objectives at the Remembering and Understanding level and to a minor extent at the Applying level [15]. A practical exam is strongly focussed on the Applying level and (through self-assessment) to some extent at Evaluating [16].

Michon's levels of the driving task

Based on Michon [17], tasks to participate in traffic are described with a triptych of strategic, tactical and operational tasks. This model is characterised by a hierarchical order. That means that operational tasks are the results of decisions made on a tactical level, like choosing road position and speed while negotiating with traffic participants e.g. when crossing an intersection. The strategic task relates to high-level decisions like choices in route-type (navigation) or journey times. Decisions made on strategic level have a primary influence on traffic efficiency. On the contrary, tasks on tactical and operational level have a direct influence on road safety. Driver training and testing therefore especially focus on how the interaction with the vehicle and other road users influences performance on tactical and operational level. To train learner drivers it is therefore common practice to start with acquiring necessary skills on an operational level. Next is to acquire skills on a tactical level. Last phase of driver training are the choices and ability to adapt to situations that are required from a strategic level.

Rasmussen's task performance levels

Rasmussen [18] provides a generic model for performing tasks, based on required effort and distinguishes three levels: *knowledge-based*, *rule-based* and *skill-based* level. At the highest knowledge-based level, human behaviour is goal-controlled and depends upon feedback-correction. Knowledge-based behaviour is often time-taking and demanding, especially the decision making. At the rule-based level, tasks are involved that are more familiar. The results of (previous) actions are available and have become like rules to the person that is performing. Once a rule is chosen the actions are carried out in a rather automatically fashion. At the lowest skill-based level, highly practiced routines are carried out without continuous feedback mechanism. When something goes wrong at this level, it will trigger task performance to be carried out at a higher level.

Relation between driving task, traffic situation and performance level

Rasmussen considers mental effort needed for executing a task and therewith addresses a dependency on individual differences in task performance. Circumstances will also influence task performance. Relating task behaviour to driving task level may help explaining how road-traffic circumstances and driver competency influence driving proficiency. Figure 1 therefore sets out driving task levels against

performance levels. For experienced drivers most driving tasks cluster in the three cells on the diagonal from upper-left to lower right. As the examples show, required performance levels (vertical axis) are influenced by differences in driver competences, and situation (i.e. familiar and unfamiliar situations). For example, navigating in unfamiliar areas may require knowledge-based performance (also from experienced drivers). When using ADAS, insight in the relationship between driving task level, situation and required performance level for supervising, may help to set requirements for drivers' ability to work with assistance systems.

		Hierarchy of driving tasks (Michon)		
		strategic tasks	**tactical tasks**	**operational tasks**
Levels of task performance (Rasmussen)	**knowledge-based**	navigating in unfamiliar area	controlling skidding car	novice on first lesson
	rule-based	choice between familiar routes	passing other vehicles	driving unfamiliar vehicle
	skill-based	route used for daily commuting	dealing with familiar intersections	vehicle handling in familiar circumstances

Figure 1 – Relation between driving task and performance level. Adopted from Hale et al. [19]

Assessment aspects														
	Failed	Preparation to take part in traffic; operating vehicle	Environment-consciously driving	Adaptation to circumstances and decisive driving	Interests of other road users	Viewing behaviour	Giving priority	Road position and place of manoeuvres	Keeping distance	Speed	Reaction to traffic lights and instructions	Reaction to road signs and other road information	Use of signals and reaction to signals	Decelerating, accelerating and stopping
Driving off														
Driving on straight and curved road sections														
Behaviour when approaching and crossing an intersection														
Merging into traffic / merging out														
Taking over other traffic and lateral movements														
Behaviour when approaching and passing special road sections														
Special manoeuvres														

Figure 2 - Assessment matrix for driving examination in the Netherlands (CBR) (Translated from Dutch)

Base requirements in driving examination

Directive 2006/126/EC of the European Union sets out minimum requirements for Member States with regard to driving tests. Based on this directive, driving licensing must consist of a theory test and a test of skills and behaviour required for driving a motor vehicle. In the Netherlands, driving examination is based on a driving exam in real traffic circumstances and a prior theory test. During driving examination a learner driver is assessed on multiple aspects summarized in an assessment matrix (see Figure 2). We used this matrix as a starting point as it is currently the governing assessment tool to evaluate learner drivers. The matrix plots a diversity of driving 'sub' tasks (e.g. speed-control or anticipation) against road-traffic situations. The matrix is used for a qualitative appraisal of the learner

driver's shown competences to take part in traffic during the different road situations. In this way the assessment takes place in relevant situations and aims to be representative for the complexity of the driving task. Because the complexity of real-world traffic situations require problem-solving, the appraisal may include solving small errors. The overarching criterion is that the learner driver shows the competences to safely participate in traffic. The Dutch licensing authority states [20]: "The examiner assesses whether you are capable of driving safely and reliably. The examiner also assesses whether you account for the interests of other traffic participants and master the road-traffic situations. (..) Completely faultless driving may not be necessary, it is the complete picture that counts".

4. Defining aspects relevant for the appraisal of a learner driver's supervisory role

This section explains our step-wise approach to define assessment aspects which are relevant for the appraisal of a learner driver's supervisory role. We aim at defining generic aspects that are generally applicable for the assessment of a driver's supervisory task independent of the specific assistant system involved. For practical reasons however, we took the competencies in system-supervision for a specific use case as a starting point, i.e.: highway cruising with Adaptive Cruise Control (ACC). In general, the approach is based on comparison between required driver's skills for manually vs. system-controlled vehicle operation. This comparison allows to identify what behaviour and skills are most demanding due to the requirements from the supervisory task and hence need most attention for driver examination.

In brief, our approach consists of minimally 5 steps:

1. First an extensive list is compiled with aspects that a learner driver is required to demonstrate. This list includes behavioural aspects, understanding of driving task levels, abilities to perform driving manoeuvres, set out against different road-traffic situations.
2. Secondly, the relevance of these aspects is evaluated, when driving manually, for a specific road-traffic situation (in our case: highway cruising).
3. Next, the aspects' relevance is again being assessed, but now while having the responsibility for supervision of an assistance system (in our case: ACC).
4. The fourth step consists of a comparison in relevance of the behavioural aspects' between manually driving and driving with the assistance system. It is expected that this comparison will show what situations and aspects are key for the assessment of competence in supervising ACC.
5. While steps 2 to 4 are based on a narrative review by the authors, step 5 is foreseen as an appraisal by expert driving instructors and examiners in order to validate and refine the conclusions from step 4.

Further steps involve repetition of the steps 2 to 5 for other systems, like Lane Change Assist (LCA) and a combination of ACC and LCA. While specifically applied to our highway cruising use case and ACC as assistance system, we will now explain our approach with step-wise comparison in more detail.

For compilation of the list with desired skills and behaviour (step 1) we used multiple sources: A written explanation of recommended driving method for driving instructors and examiners provided by the Dutch driving license authority [13]; The book 'Mobility and behaviour' [21]; Course material for vocational training of driving instructors; An interview with a driving school director [22]; Author Veders' experience as a driving instructor; And several papers on acquisition of driving skills – like [23], [24] and skills to interact with ADAS – like [7], [9], [25], [26], [27]. The collected behavioural aspects were grouped in 8 categories: Viewing behaviour; Keeping traffic rules; Anticipation road and traffic situations; Required driving task level; Preparation traffic manoeuvre; Execution traffic manoeuvre (e.g. overtaking); Special manoeuvres (like taking a rush-hour lane); Giving and receiving (vehicle) signals. This collection resulted in a general list of relevant behavioural aspects for practically all driving situations. For our use case (highway) the category *Preparation traffic manoeuvre* appeared most relevant and contains elements like appropriate timing of lane change manoeuvres, accounting for the interests of other road users and safe control of required spacial cushion during overtaking. The next steps focus especially on differences in required drivers' skills between manually and automatically driving control for this category within our highway use case.

Behavioural aspects' relevance in case of human-control compared to system-control

While being experienced road safety researchers as well as one author being a professional driving instructor, the first appraisal of behavioural aspects' relevance (step 2) is based on a narrative review carried out by the authors. In this step it was identified what behavioural aspects are specifically relevant to assess when a (learner) driver manually controls a vehicle on a highway. The relevance was expressed in three levels ranging from 0 to 2. Level "0" was assigned when the aspect was considered not relevant for our use case. Level "1" indicates that the behavioural aspect is relevant. Level "2" indicates that the aspect is very relevant to such extent that without demonstrating the particular behaviour there would be a direct danger of accidents. With level "1" there is no such imminent danger for traffic safety. In step 3 we used the same scale for assigning relevance to the assessment aspects, but now the appraisal focussed on relevance for the remaining driving task when the ACC system controlled highway cruising. That is: The human driver needed to take supervisory control. Finally we compared the scores of relevant skills between the conditions of manual control and supervisory control. The differences show how required skills of a learner driver change when using ACC instead of manual control of highway cruising. Based on this comparison the next chapter collects the aspects that are most important to assess when a learner driver needs to fulfil supervisory control.

5. Assessment aspects of learner driver's supervisory role during driving examination

Based on determining the relevance of the collected aspects for the assessment of the driver's role during system supervision (and specifically focussing on highway cruising with ACC), we now explain what aspects appear to be most important to assess a learner driver's role as supervisor and responsible

operator of system controlled vehicle functions:

- *Assessment on tactical level: system understanding in relation to traffic circumstances*
  While drivers take up a supervisory role (e.g. when driving with ACC), the remaining tasks for the driver generally changes from the operational level to the tactical level. This makes their role more prone to misunderstanding, like confusion about the appropriate circumstances in which the system can be applied. The appraisal of driver's supervisory role should therefore include an assessment of sufficient awareness and correct understanding of system rules, like when a specific system can be safely applied or not and how this is influenced by changing road-traffic circumstances.
- *Assessment of special manoeuvres*
  More attention is needed for the assessment of special manoeuvres, like being in traffic congestion, or taking a rush-hour lane. This is because the learner driver then needs not only to understand the road-traffic situation itself, but also the system mode and what the system's capabilities are. Especially important is to understand and recognise the limits of the system and understand how road-traffic circumstances (incl. weather) influence the system's reliability. Therefore, the assessment of system understanding needs to be explicitly addressed in driving examination and may be an additional part of the theory test.
- *Assessment of adequate perception of relevant road-traffic elements*
  The assessment of a learner driver's scanning behaviour becomes more difficult because perception of road-traffic elements is partly taken over by ADAS. For example ACC reduces the need for longitudinal scans of the car in front and Blind Spot Detection reduces the need for glances at the side mirrors during highway cruising. For the assessment of learner drivers' perception of relevant road-traffic elements during his/her supervisory role new tools may therefore be necessary (like eye tracking to assess scanning patterns).
- *Adequate anticipation*
  The assessment of drivers' adequate anticipation and correct projection how traffic situations develop, will become more difficult, yet (even) more relevant. This is because during manually driving examiners receive subtle cues from the learner driver that may now be covered up by system's actions. An example is that changing foot position and taking the gear changer at hand might be a strong cue during manually driving about the learner driver's anticipation of increased traffic density when approaching an entrance lane – behavioural cues that remain unnoticed as long as the ACC is able to deal with the situation. Similar as for the previous aspect, the assessment of drivers' anticipation may require new tools (like eye tracking to assess the learner driver's scanning patterns or probe-taking to evaluate the learner driver's observation of relevant elements in the road-traffic environment).
- *Assessment to account for the interests of other traffic participants*
  Closely related to the recommended increased attention to adequate anticipation, is that

assessment to account for the interests of other traffic participants becomes particular important. At first, this is because ADAS (like ACC) have poor contextual knowledge in order to be always aware of these interests (for example ACC only "sees" the vehicle directly in front). Safeguarding these interests is therefore an important responsibility of the driver. Hence, the driver should observe signals from other road users and act accordingly. Moreover, drivers are in danger to become less aware of the interests of other road users, because they are placed rather remote from the control loop while using ADAS. Many studies confirm that being remote from the control loop raises reaction times (e.g. [11], [12]). Furthermore, operating the system captures attention to the dashboard and within the vehicle, while accounting for the interests of other road users requires to have attention outside the vehicle [28]. For assessment of supervisory control accounting for the interests of other road users is therefore of utmost importance.

For examination of a driver's traditional role the overarching criterion counts that the learner driver shows the competences to safely participate in traffic. Based on the summary above the overarching criterion for a learner driver's supervisory role is: Does the learner driver remain in control of the assistance function? It obviously testifies of insufficient supervision if an ADAS performs an emergency task which comes as a surprise for the learner driver.

6. Discussion and final conclusion

The introduction of automated systems in cars changes the driving task from actively operating the vehicle to being a supervisor with the responsibility for safe vehicle operation. Despite this changing role of the driver, assessment of required competences of a learner driver to act as a supervisor is not included in the appraisal of driving proficiency. This paper therefore set out a first step to assess a learner driver's role as supervisor and responsible operator of system controlled vehicle functions. For practical reason we started our appraisal of required competencies in system-supervision for a specific use case (i.e.: highway cruising with Adaptive Cruise Control) and took the Dutch situation of driving examination as a reference.

Competencies that define a learner driver's supervisory role

Our appraisal of required competencies for a learner driver to adequately act as system supervisor brought an important observation: ADAS causes interruptions in task levels required from the driver. While activated ADAS mostly reduces the required task level for the driver, it now and then raises the required task level above levels that would be necessary if driving without system assistance. For example, during manually driving lane changing is considered an operational task. When driving with ACC however, the appropriate timing of a lane change manoeuvre and appraisal how the road-traffic situation and other traffic participants will be influenced while ACC is active, need additional

consideration. This raises the required task efforts to tactical and strategic level. The rise in task level that we expect is line with results from previous research [9], confirming that drivers with ACC make more strategic decisions for overtaking. According to Rasmussen's considerations on task levels and performance, the required raised levels of task performance may increase the risks for misinterpretation and misjudgement [18]. Higher levels of reasoning are necessary in comparison to the operational task level, which may be experienced as more effort-taking. Especially in situations when interruptions in required task level occur frequently, safe operation might be at danger. For a closer consideration how interruptions and changes in task level may influence driver's performance we propose to expand Michon's model of the driving task with a new base level called "supported by technology". (This base level could be added as an extra column at the outer right in Figure 1.)

Base assessment of a learner driver's supervisory role

The criterion for adequate execution of the supervisory role is essentially: *Does the learner driver remain in control of the assistance system?* Based on the collected relevant aspects for the assessment of the driver's role during system supervision the assessment of this role comes down to the appraisal whether the learner driver is capable of switching between the required tasks levels. This is especially important because the expected increase in assistance systems [1] will raise the frequency of interruption and will increase the necessary performance level for the remaining tasks required from the driver. This in itself is effort-taking, while at the same time anticipation and accounting for the interests of other road users need to be safeguarded. These aspects need strong attention for the assessment of a learner driver's supervisory role. The assessment of the supervisory role should also include judging the learner driver's application of system knowledge, like understanding the system's capabilities and limitations and how these interact with road-traffic situations.

Limitations and further research

For practical reason our appraisal of required competencies in system-supervision focussed at first on highway cruising with Adaptive Cruise Control. Since the identified relevant skills and competencies were derived from generic descriptions of the driving task and overall recommendations for driving competency the results seem to justify their validity of required competencies for supervision of ADAS in general (not only ACC). However to strengthen this claim our step-wise appraisal must be applied to other systems as well, like Lane Keeping Assist and combinations of assistance systems. It also needs to be expanded for use cases other than highway cruising, like city driving. Although our approach was based on an extensive literature research and one of the researchers is an experienced driver instructor, a larger appraisal by more driving experts, including driving examiners (step 5) needs to take place. Both activities to expand appraisal of required learner drivers' competences for more ADAS as well as include a larger group with expert evaluators are foreseen for further research.

Final conclusion

In an increasing degree driving assistance systems are introduced as semi-automated system. Contrary to general thoughts, automated driving may not necessarily make the whole driving task easier. It will only do within the boundary conditions suitable for automation. These systems therefore introduce a new responsibility for the driver: supervision of safe system operation. This new role demands additional skills which are currently not being assessed in driving examination. This paper explored an approach to include the appraisal of learner drivers' competencies for supervising system controlled functions. It was acknowledged that ADAS causes both interruptions and temporarily rises in task-level required from drivers. An important assessment will therefore be whether the learner driver is capable of switching between the required tasks levels, while safeguarding correct anticipation and the interests of other road users. The results set an important step towards driver training and testing that includes drivers' ability to correctly work with automated driving systems in order to take full advantage of them.

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