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Working towards a Meaningful Transition of Human Control over Automated Driving Systems

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Abstract: Automated vehicles with partial automation, supporting both longitudinal and lateral control of the vehicle, are currently available for the consumer. The consequences of driving with this type of advanced driver assistance systems is not well-known, and could cause the human driver to become out-of-the-loop, or cause other types of adverse behavioural adaptation, leading to dangerous circumstances. Therefore, understanding what the effects of driving with automated driving systems are from the human driver's perspective is becoming imperative. By means of a literature-based approach, this paper presents a framework of human control over automated driving systems. This framework shows the quantified distribution of human behaviour over all the levels of automation. The implications, discrepancies and apparent mismatches this framework elicits are discussed, and recommendations are made to provide a meaningful transition of human control over automated driving systems.

1. Introduction

It is becoming increasingly important to address Human Factors issues with automated driving systems, as consumer vehicles become equipped with exponentially increasing amounts of advanced driver assistance systems that take over parts of the driving task previously performed by the human driver. With the partially automated vehicles (SAE level 2; [1]) already on the road today, both the longitudinal (braking/accelerating, e.g., adaptive cruise control) and lateral (steering, e.g., lane keeping assist) control of the vehicle is being taken over by an automated driving system. Inevitably, this and future technology enabling higher levels of automation will cause out-of-the-loop problems [2], mode confusion [3], and behavioural adaptation [4] issues that need urgent reconsideration in order to maintain safe driving with automated vehicles [5].

Therefore, the transfer of control from the human driver to the automated driving system and vice versa needs to follow a safe and meaningful process that circumvents or even solves the aforementioned issues. The concept of maintaining a form of meaningful human control over automated systems is not new, as it originated from the field of autonomous weapon systems [6]. This concept encompasses all forms of control (i.e., not solely operationally, but also tactically and strategically; cf. [7]) of a human being over an automated system. A recently developed philosophical account defined two conditions that need to be met in order for any system to remain under meaningful human control, namely 'tracking' (i.e., a system should always be able to respond to a human's moral reasons), and 'tracing' (i.e., it should always be possible to trace back how a system came to a decision) [8].

However, in order to be able to attach a meaningful form of control to a human driver—and thus a safe driving behaviour—it is first necessary to assess what behaviour is involved in driving a vehicle (and with automated driving systems), from a human-oriented perspective [9]. Without understanding the full extent of human behaviour within an automated vehicle, it if difficult to know what the notion of 'control' applies to. A taxonomy often used to compare with or extend driver behaviour models from is the taxonomy of Rasmussen [10] (see e.g., [9]).

The taxonomy of Rasmussen [10] distinguishes three levels of human behaviour (explained in more detail in section 2.2) based on the assumption that humans are goal-oriented and thus not mere input-output systems that would structurally adhere to the commands given to them. His assumption encompasses that humans need *reason* (or *meaning*) for a given action, and thus lays the foundation for a human-oriented framework of meaningful human control over automated driving systems.

The question we aim to answer in this paper is: What (types of) human behaviour is involved in automated driving, and to what extent does this behaviour get affected by the introduction of automated driving systems?

In this paper, a quantitative rather than a qualitative approach is taken. Since a quantification of human behaviour with automated driving systems is currently missing, we aim for this approach to serve as a foundation for future research.

2. Development of a framework of human control over automated driving systems

In this literature study, a framework of human control over automated driving systems was developed by means of setting the taxonomy of the SAE related to on-road motor vehicle automated driving systems [1] against the classification of human behaviour determined by Rasmussen [10]. This created a 6x3 framework, entailing 18 fields, each of which to be filled by quantitatively assessing how many driving tasks are subject to each field. The quantitative assessment was done by thorough literature research and, in several occasions for which literature not yet exists, logic and deductive reasoning.

2.1. SAE levels of automation

The levels of automation set out by the SAE are divided into six categories, ranging from level 0 (no automation, or manual driving) to level 5 (full automation). The SAE specifies that these levels are descriptive and technical, rather than normative and legal, meaning that they distinguish these levels by assessing what type of driving task is being taken over by the automated driving systems (e.g., if the execution of steering and acceleration/deceleration is being performed by the automated driving systems, while the monitoring of the driving environment is still to be performed by the human driver, this automated driving systems would be level 2 [partial automation]).

Specifically, the following definitions belong to the six levels of automation:

Level 0: “The full-time performance by the *human driver* of all aspects of the *dynamic driving task,* even when enhanced by warning or intervention systems”.

Level 1: “The *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*”.

Level 2: “The *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*”.

Level 3: “The *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*”.

Level 4: “The *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task,* even if a *human driver* does not respond appropriately to a *request to intervene*”.

Level 5: “The full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*”.

2.2. Classification of human behaviour (Rasmussen, 1983)

In his paper, Rasmussen [10] distinguishes three types of human behaviour, namely skill-, rule-, and knowledge-based behaviour. He defines skill-based behaviour as acts or activities which take place without conscious attention or control, and which is automated and highly integrated. Rule-based behaviour is defined as routinely executed acts or activities that follow a stored rule or procedure, often from instruction or preparation. Its distinction from skill-based behaviour depends on the level of training and attention of the person, where skill-based behaviour is unconscious, and rule-based behaviour is consciously based on explicit recollection of facts. Knowledge-based behaviour is the performance of an act or activity during unfamiliar situations, and is goal-controlled. Here, a person needs to plan his/her actions, evaluate those, and consider the best response by functional reasoning. Usually, this is done by selecting from (parts of) previous similar experiences, and piecing together a novel reaction to a novel situation.

2.3. Filling in the blanks: the baseline (SAE level 0)

To set a baseline for the set of skills, rules and knowledge required during (automated) driving, in this paper we consider the case of the driver who recently successfully completed their basic driver training course in a European country. With regard to the choice of this baseline, rather than an ‘ideal’ or ‘average’ driver, we believe that these novice drivers are a reasonable baseline for this study, as they represent and express minimal requirements for being allowed to drive a regular vehicle, which would *theoretically* encompass all drivers’ skill-, rule-, and knowledge sets.

Therefore, we aimed to find a skillset, laid out by a European organization, which is mandatory to possess in order to acquire a European driving license. This skillset is found to be laid out by the CIECA Road Safety Charter working group’s Harmonisation of the Assessment of Driving Test Candidates [11]. This working group identified seven categories of driving skills necessary for passing a driving test, ranging from preparatory skills (e.g., checking the oil level and tyre pressure), via vehicle control (e.g., steering and accelerating/decelerating), to traffic adaptation skills (e.g., merging into traffic), each with their own (sub)categories. A total of 128 unique skills were extracted, which serve as the baseline for driver skill-based behaviour (see Table 1, top left field).

The baseline set of rule-based behaviour was derived from a 1968 convention on road traffic, during which the rules of the road were laid out to increase road safety throughout the European continent, commonly known as the Vienna Convention [12]. In the Vienna Convention [12], 56 articles spread over six chapters discuss everything that enables safe driving in Europe. Excluding some exceptions that are for governmental bodies specifically, the contents of Chapter 2 to 5 are important for every driver to know, which describe the general rules of the road (Ch. 2), and vehicle- (Ch. 3), driver- (Ch. 4), and cycle/moped condition requirements (Ch. 5). Furthermore, since 1968, two important changes have been made in light of the introduction of automated driving systems, namely the inclusion of a new paragraph (5bis) in Article 8, and the amendment of Article 39 [13]. These changes have been included in this paper. The Vienna Convention lists a total of six chapters, in which 37 articles cover 151 main rules that are directly or indirectly related to motor vehicle drivers. In total, these 151 main rules cover 254 unique (sub)rules which form our rule-based behaviour baseline (see Table 1, middle left field). Examples of these rules range from general rules such as that one should not endanger or harm others, and that one should drive on the correct side of the road (left or right, depending on the country one is in), to more complex rules regarding the weight and dimension of goods one can load onto their vehicles, and registration and licensing rules.

2.3.1. The knowledge gap

The third and final step in setting the baseline was finding a set of knowledge-based behaviour for drivers who just received their license. This, however, proved to be no easy task, as this entailed everything else the sets of skills and rules haven't covered yet. Moreover, in search for such a set, the term 'knowledge' needed to be redefined in order to retrieve valuable information, since 'knowledge' as a key search term encompassed too much transient topics. As Rasmussen's [10] definition states this type of behaviour is related to unfamiliar situations, where the driver's behaviour is heavily dependent on the task-capability interaction [14], one can argue this type of behaviour is situationally induced behaviour [15]. Therefore, we aimed to find a set of advanced driver training courses, as those courses aim at training unfamiliar situations. Unfortunately, no such set yet existed. However, some documentation reported several selected countries in Europe [16, 17]. Each reference cited in these documents has been carefully studied, and their results have been summarized (disregarding the results found from non-EU countries; see [17]).

This approach resulted in a set which could be divided into four types of situationally induced behaviours, namely *roadway*-, *traffic*-, *environment*-, and *car*- induced behaviours [15], and totalled 64 unique knowledge-based behaviours one may have to call upon during manual driving as a recently licensed car driver in Europe (see Table 1, bottom left field), such as identifying and recognizing as well as handling under- or oversteer, predictive steering, and defensive driving techniques, such as reciprocation and joint-action.

2.4. Driver Assistance (SAE level 1) and Partial Automation (SAE level 2)

After having set the baseline sets, the effects of the introduction of automated driving systems to human behaviour was assessed. The amount of research done regarding the effects of automation on driver skill is very limited (only works from [18] and [19] were found that were somewhat related), as most research limits itself (understandably) to one or two individual skills like braking or steering. For rule-based behaviour, only the works of [20] were found to be somewhat relevant for this study, so it appeared that a literature-based approach was not warranted hereon forward. Therefore, an inventory of all existing advanced driver assistance systems was sought, and a systems-based approach was taken. This inventory lists six systems that include either longitudinal or lateral assistance, ranging from antilock braking systems to automated parking assistance [18] (see also [21] for a list per vehicle manufacturer). Further investigation found two more variations of such systems, thus totalling eight advanced driver assistance systems currently implemented in consumer market vehicles.

Inspection of these systems regarding their impact on driver skill-, rule-, and knowledge-based behaviour based on the SAE definition, showed that the amount of behaviours required from the driver differs depending on the system that is being used. For example, the autonomous emergency braking system only takes over the skill of making an emergency brake, whereas adaptive cruise control takes over the skill of braking smoothly when a car is in front of you, and several other skills involved in speed adaptation (see [19]). Since the SAE defines level 1 systems to have *either* longitudinal *or* lateral control, the amount of skills required while driving with such a system is flexible. Because driving with advanced driver assistance systems is yet to be included within basic driving courses, no added skills are foreseen as of yet (see Table 1, top second left field).

Regarding the amount of rules a driver needs to adhere to during driving with SAE level 1 systems, we consider the SAE definitions of the levels of automation as added rules to adhere to. Further European legislation regarding automated driving systems are—albeit under development—currently non-existent, although several separate European and non-European countries are progressively adapting rules regarding autonomous vehicles (see e.g., [22]). Next to the additional SAE rules, again, depending on the system in use, varying amounts of rules are being taken over by the advanced driver assistance system. For example, a lane centring system needs to adhere to Article 10, rule 3, concerning the position within a lane, thus making it obsolete for the human driver to adhere to this rule (while driving with that system activated). Adaptive cruise control will, in its turn, need to adhere to Article 13, rule 2, regarding speed limits, and rule 5, regarding the distance between vehicles (see [20]). The results are presented at Table 1, middle second left field.

Lastly, the introduction of novel systems such as advanced driver assistance systems inadvertently introduce novel situations. Thus, in contrast with skill- and rule-based behaviour, these systems will *add* drivers knowledge-based behaviour more than they take over. Although little is known about what situations may occur, several knowledge-based behaviours are expected to be requested by driving with such systems, such as coordinating, cooperating and collaborating with the activated system, but also understanding the distribution of tasks between the driver and the system, as well as knowing when it is safe to engage in secondary tasks [18]. Most of these situations are thus concerned with the new supervisory task of the driver. Note that SAE level 1 systems could potentially take over some knowledge-based behaviour (i.e., a traction control system could take over advanced turn-negotiating techniques, albeit to a limited extent), but this does not outweigh the amount of additional knowledge-based behaviour introduced by these systems. Also note that, especially for novice drivers, the (negative) effect driving with advanced driver assistance systems has on human behaviour is not to be underestimated (see [23]).

With SAE level 2 —or Partial Automation— systems *both* longitudinal *and* lateral control is being taken over by the automated driving system. This could potentially entail a vehicle that has adaptive cruise control with a lane-centring system, or a vehicle that has an automated parking system. Although somewhat dependent of the system, this basically entails that for the human driver the required amounts reach the maximum deviation from the baseline seen at SAE level 1 systems for both skill-, rule-, and knowledge-based behaviour (see Table 1, third left column).

2.5. Conditional Automation (SAE level 3)

From the technical perspective of the SAE, a level 3 automated driving system entails a system that takes over *all* of the *dynamic driving task*. This basically means that all that is left for the human driver to do is to take the necessary preparatory measures before stepping into the vehicle, and drive off automatically. Henceforth, regarding the required amount of skills while driving with a SAE level 3 automated driving system, a massive drop can be foreseen, as none of the skills trained during driver training are called upon, apart from, for example, being able to check the tyre tread and oil level, that the lights still work, and that the mirrors and windows are clean. The entire dynamic driving task, from changing gears to merging in traffic (cf. [19]), will be performed by the automated driving system.

The same applies to the amount of rules the human driver needs to adhere to. Many of the driving-related rules will have to be considered by the automated driving system instead of the human driver, such as the rules regarding overtaking, the priority rules, and rules regarding interacting with vulnerable road users. Nevertheless, a substantial amount of rules are left at the responsibility of the human driver. For example, rules regarding the registration, as well as the loading of your vehicle, and regarding the consequences of disobeying any rule, are still at the human driver's responsibility. Notably, in the event of the vehicle getting involved in an accident—even though the system should be capable of avoiding accidents, as that is essentially part of the dynamic driving task—three rules regarding accident handling will apply to the human driver. Since the automated driving system should be designed to such an extent that an accident should not happen, this situation must be given special attention in the framework (see Table 1, asterisk sign).

When considering the amount of knowledge-based behaviour involved in driving with a SAE level 3 automated driving system, it becomes apparent that this introduces unknown situations to such an extent that quantifying the amount of knowledge-based behaviour required from a human driver is becoming guesswork (see Table 1, question mark sign). Nevertheless, an estimation has been made, based on the SAE's definition of level 3, the consequences of the introduction of automation at SAE levels 1 and 2, and consequences mentioned in [18]. Since most knowledge regarding the dynamic driving task is becoming redundant at this level of automation—as the automated driving system now takes care of that—the amount of knowledge-based behaviour also experiences a decline. What remains are the knowledge-based behaviours regarding car-specific behaviours and understanding one's own behaviour whilst driving (with and without such an automated driving system). However, within this level of automation, one also has to consider the ironies of automation [24], one of which is the deterioration of (unused) skills and rules to a knowledge-based level (see Table 1, exclamation mark sign; see also [18] and [3]).

Up to SAE level 3 automation, the SAE defines that the human driver is expected to serve as a fall-back to perform the dynamic driving task in case of an emergency, like a system malfunction [1] (see Table 1, bold line; see also [25]). This means that for all these levels (SAE levels 0 to 3), the human driver is expected to be able to perform as if (s)he were driving a manual vehicle. Given the considered ironies of automation discussed above, this appears to be misplaced.

2.6. High Automation (SAE level 4) and Full Automation (SAE level 5)

Beyond SAE level 3, where the human driver is still expected to act as a fall-back for safely handling the vehicle in critical situations, most of the quantification of human driver skill-, rule-, and knowledge-based behaviour relies on speculation and debate. Vehicles with SAE level 3 automation don't exist yet, let alone SAE level 4 or 5 [26], however, as with SAE level 3, certain assumptions can be made regarding a human driver's skill-, rule-, and knowledge-based behaviour.

For example, it may be reasonable to assume that with a SAE level 4 automated driving system the human driver will still be responsible for preparing their own vehicle before driving off, while on the other hand not expecting them to still remain in a driving position anymore, making room for other activities such as working on a laptop or reading a book, or even sleeping [27]. Simultaneously, however, one has to wonder how much use a safety belt would still have under such circumstances, or whether people would still actually own their own vehicles, and thus whether or not they still need to be skilled in doing their own safety checks prior to their drive [28].

Where with SAE level 3 automated driving systems the human driver still plays a key (fall-back) role within the driving task, (s)he can be taken completely out-of-the-loop with SAE level 4 automated driving systems. Therefore, certain human driver-oriented rules may not (need to) apply anymore, such as having a physically and mentally fit driver behind the steering wheel, potentially opening the gate for disabled, children and the elderly [29]. As with driver skill-based behaviour, it is however uncertain to what extent certain preparatory rules still apply (e.g., registration rules), while others are likely to still to remain in place (e.g., loading rules). Up to full automation (SAE level 5), it is up to everyone's imagination as to what extent a 'driver' of such a vehicle still needs to abide to a (if any) rule (e.g., will "Don't litter" [Article 7, rule 2] be covered by a fully autonomous vehicle?).

Ultimately, knowledge-based behaviour is unlikely to be part of a driver's task demand while driving a SAE level 4 or 5 automated vehicle, but nevertheless certain situations may occur that places a driver in unknown territory, albeit hard to pin an exact number to that.

Table 1. Framework of human control over automated driving systems. he numbers represent the (range of the) total amount of behaviours that are expected from a novice driver to be present during the respective levels of vehicle automation.

Automation / Human	SAE 0	SAE 1	SAE 2	SAE 3	SAE 4	SAE 5
	No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
Skill	128	127 - 114	114	43	40 - 0?	39 - 0?
Rule	254	255 - 250	250	69* - 66	51 - 29?	29 - 0?
Knowledge	64	64 - 80	80	33?!	0-?!	0?

| Fall-back to human up to SAE 3, means human needs at times adhere to SAE 0 levels.

* In case of accident; i.e., in case the automation is *not* capable of avoiding an accident.

? Higher levels of automation involve unknown situations and definitions.

! Within this stage, driver skill- and rule-based behaviour may already deteriorate to knowledge-based, adding up to a driver's required knowledge-based behaviour.

3. Implications

3.1. The decline in skill- and rule-based behaviour

As can be seen in Table 1, a negative trend in the amount of required skills and rules coincide with the introduction of increasingly autonomous driving systems. With extended exposure to driving with such systems activated, the consensus is that an actual loss of skill can be expected (e.g., [19, 24, 30]). Only by consistent maintenance of these skills, and rehearsal of these rules, one could avoid having these deteriorate to a knowledge-based behaviour level (cf. exclamation mark sign at Table 1), but that requirement simultaneously beats the purpose of automated driving systems altogether, as these systems—as goes for many other automated systems—are predominantly there to replace the human as the operator [31].

3.2. The rise and fall of knowledge-based behaviour

Contrary to the trend seen with skill- and rule-based behaviour, knowledge-based behaviour first experiences a rise in requests for the human driver. The introduction of advanced driver assistance systems appears to introduce more novel situations than that they dissolve. Behavioural changes such as, but certainly not limited to, becoming complacent and having to supervise an automated system will have to be accounted for in order to ensure safe driving with such systems (e.g., [32, 33, 34]).

Only during SAE level 3 automated driving we begin to see a decline in the request for knowledge-based behaviour, which is because of the execution of "all aspects of the dynamic driving task" by an automated driving system [1]. However, since the SAE also states that they have "the expectation that the *human driver* will respond appropriately to a *request to intervene*", at least the behavioural changes mentioned above are to be expected to become of importance to a driver's knowledge-based behaviour. To what extent a *request to intervene* requires knowledge-based behaviour is yet to be determined, but quick regeneration of awareness of the situation at hand is considered to be one of the requirements (e.g., [35, 36, 37]).

3.3. The human driver as a fall-back mechanism

As mentioned in section 2.5, the human serving as a fall-back in case of emergency appears misplaced. At the stage where a person has been driving with a SAE level 3 automated driving system for extended periods of time, reclaiming the wheel may be futile as the majority of skills, rules and knowledge necessary for safe driving have not been mobilized in this time (see Table 1). Especially when this level of automated driving encompasses novel techniques such as platooning, more exacerbating behavioural adaptations may occur, such as carryover effects [38], and loss of task engagement [39], to name a few. Given the fact that a deviation in skill-, rule- and knowledge-based behaviour from manual driving occurs throughout all levels of automation, it appears paramount to reconsider the driver's role as a fall-back mechanism during automated driving, especially when given the time to 'forget' about their learned skills and rules (see also e.g., [18] and [24]) .

3.4. SAE level 4 and 5 automation: the path of the unknown

Automated vehicles of SAE levels 4 and 5 are currently only things of the future. Therefore, little knowledge exists on what the effects of those automated driving systems would be. One thing is clear though, and that is that the human will become completely removed from the driving task. Based on the framework presented at Table 1, we have to assume that at this stage, the driver is (almost) completely incapable of resuming manual control, so even a gradual decrease in the level of automation could potentially have disastrous consequences. From this, it appears that the fall-back threshold up to SAE level 3 (bold line at Table 1) has become a point-of-no-return, in the sense that manual intervention is not expected according to its SAE definition, but also not possible anymore.

This does not mean, however, that by having taken into account all of the dynamic driving tasks by the automated driving system it has achieved an infallible machine. It also implies that the as of yet unforeseen newly introduced situations that come with these new type of automated driving systems have to be taken into account (cf. Table 1, two bottom right fields). To give the reader some examples of what might be laying in the autonomous driving future, see [40] and [41].

Lastly, regarding new legislation to be set out by European legislator bodies, the new situations that will arise also requires a legal safety system design. Example suggestions for applicable rules for the new type of driving with automated systems are presented in [20].

4. Limitations, Recommendations, and Future Research

4.1. Limitations of this research

This research attempted to develop a framework of human control over automated driving systems by *quantitatively* assessing the effects various levels of automation has on human behaviour. This means that the framework presented in Table 1 does not provide answers about the effects on the *quality* of human behaviour. It can be argued that certain skill-, rule-, or knowledge-based behaviours have more weight than others in the driving task.

Another limitation of this research is that although a literature-based quantitative approach was attempted in this study, not all fields in the framework were viable for this approach, given the futuristic nature of the higher levels of automation (e.g., SAE level 4 and 5). The actual numbers may be completely different when actual SAE level 4 and 5 automated driving systems exist.

A third limitation is that the framework is not empirically tested. Although validated by thorough literature research, empirical testing of the framework could provide more insights into its validity.

The final point of discussion that should be made here is that the adopted classification of human behaviour of Rasmussen [10] is not the only suitable, nor necessarily the best classification that could be used for the development of such a framework. Examples of similar classifications of human behaviour are the Markov dynamic model of driver action [42], the conceptualisation of a driver's task [43], or the hierarchical structure of the road user task [7]. Michon [7] further summarizes several more in-depth models of human behaviour (see also [44] and [45]). Although the classification used in this paper provided valuable insights that could help increase safety in driving with automated driving systems, we will not discourage attempts of frameworks with different categorisations, as those could potentially point out other bottlenecks and design issues related to human behaviour.

4.2. Mismatch between supply and demand

The developed model sheds light on a serious problem with respect to the role a human driver is supposed to play within an automated driving system. At various levels of automation, large deviations from manual driving concerning skill-, rule-, and knowledge-based behaviour raises issues regarding what we still can and still are supposed to do (cf. [23]). The apparent mismatch between the availability of skills, rules and knowledge at especially the higher levels of automation, and what is requested from the driver (e.g., acting as a fall-back) suggests that the current transfer of control within an automated driving system needs an overhaul, and, more importantly, a (meaningful) human-oriented transfer of control.

Important to note is that the issue with the transfer of control is not only the mismatch between supply and demand, but also the possibility of mode error if this transfer is not communicated appropriately [3].

4.3. Future research

The developed framework presented in this paper suggests a human-oriented taxonomy of levels of automation, in order to secure a safe and meaningful transfer of control. Future research should investigate how such a human-oriented taxonomy could look like.

Next to empirically testing the validity of the framework presented here, it is suggested to have the to be developed human-oriented taxonomy empirically tested too.

Furthermore, predictive models like those used in economics or econometrics, or those used in the estimation of logistics- and fuel consumption benefits of platoons (see e.g., [46]), could be used to attempt more sound calculations of the effects of the higher, futuristic, levels of automation.

Lastly, a qualitative approach could be made regarding a framework that assesses the effects of automated driving on human behaviour.

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