ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ СОФИЯ

Том Volume 59 2026 Брой Issue 3

ANNUAL OF THE UNIVERSITY OF ARCHITECTURE, CIVIL ENGINEERING AND GEODESY SOFIA

DOI: 10.71167/uaceg.2026.590312

Received: 19.01.2026
Accepted: 14.07.2026

NOVICES' PHYSIOLOGICAL REACTIONS, ACCEPTANCE, AND ASSESSMENT OF THE CONTROLLABILITY OF A LEVEL 2 SYSTEM IN REAL TRAFFIC

K. Reinprecht[1], P. Zellnig[2], B. Hristov[3]

Keywords: *driver assistance systems, SAE Level 2, physiological reactions, electrodermal activity, system failure, system drop, eye tracking, heart rate, perceived comfort*

ABSTRACT

Driver assistance systems are becoming more prevalent in the market. SAE Level 2 systems are now available in affordable price segments and in used vehicles. Nonetheless, very little is known about how people without any experience with driver assistance systems perceive and accept such systems, which take over longitudinal and lateral control of the vehicle, or what physiological consequences an experienced system failure (drop, crash) can have for the respective driver.

To answer these questions, a real-life driving study was conducted. Nineteen people (9 female and 10 male; M = 36,7; SD = 9,9) with no experience with Level 1 or 2 systems were recruited for the study. After an introduction and explanation of the Level 2 system, the test subjects were asked to complete a 50-minute drive in the vehicle. The route was selected to ensure activation of the installed Level 2 function in the test vehicle (BMW 5 Series). The route consisted of three sections: an urban road, a two-lane rural road, and a highway.

The system was activated when the following conditions were met: a vehicle was present in front, the vehicle was driving on a highway, there were visible lane markings, and the speed was below 60 km/h. The participants were instructed to follow a moving truck on the highway

[1] Klaus Reinprecht, Dr., Inspectio Research Institute, Dieselstraße 28, 85748 Garching near Munich, e-mail: k.reinprecht@inspectio.de

[2] Peter Zellnig, Inspectio Research Institute, Dieselstraße 28, 85748 Garching near Munich, e-mail: p.zellnig@inspectio.de

[3] Borislav Hristov, Prof. Dr.-Ing., Department of Engineering, Chair for Road and Transportation Engineering, University of Applied Sciences Berlin (HTW Berlin), Wilhelminenhofstraße 75A, 12459 Berlin, e-mail: Borislav.Hristov@HTW-Berlin.de

for as long as possible. The results show a significant decrease in the acceptance of the system as well as in the confidence in the Level 2 system as the number of system drops increases. However, the subjective perception of the increase in comfort provided by the system shows that, despite the frequent drops, the ride was perceived overall as comfortable. Additionally, most participants felt that the system drops were justified. Furthermore, the ride was experienced as very safe and controllable.

Electrodermal activity (EDA) was measured using a two-electrode recording system. This method quantifies changes in skin conductance between two surface electrodes and serves as an indirect measure of autonomic nervous system activity and physiological arousal. An analysis of the EDA responses during the 10-second intervals before and after a system failure revealed no statistically significant differences. These results suggest that the first system failure does not cause a measurable change in electrodermal activity and therefore does not lead to a significant physiological response.

1. Introduction

Advances in vehicle technology and the introduction of semi-autonomous driving systems have made the physiological reactions of drivers increasingly important. Level 2 driver assistance systems, such as those offered by Tesla and Audi, enable semi-autonomous control, in which the vehicle takes over certain driving tasks but still requires active supervision and intervention by the driver [1]. These systems present new challenges for human-machine interaction, affecting the psychophysiological responses of drivers as well as their perception of controllability and acceptance.

1.1. Acceptance and Controllability in Human-Machine Interaction

The acceptance of driving systems, particularly semi-autonomous technologies, is essential for successful implementation and use [3]. Drivers must understand, trust, and be able to use the system in different driving scenarios. A key question is the extent to which drivers can maintain control over the vehicle and system. A high degree of perceived controllability is crucial for acceptance of such systems. When drivers feel they can intervene in any situation, their trust in the system increases and their cognitive load decreases [4].

A key element of this interaction is drivers' physiology, which manifests as heart rate, skin conductance, and eye movement. These physiological reactions offer valuable insights into drivers' perceptions regarding acceptance and controllability. Studies have shown that the level of physiological stress experienced when using Level 2 systems depends heavily on the complexity of driving tasks and the frequency of system takeover [5]. High stress levels may indicate insufficient control perception and uncertainty about the system's behavior, which can lead to reduced acceptance.

1.2. Literature, Theory, and Derivation of the Research Question

The literature on autonomous vehicle technology extensively covers the topic of driver acceptance in relation to physiological reactions. An important theoretical basis is provided by the Technology Acceptance Model (TAM) [2], which shows that perceived ease of use and perceived usefulness are crucial for acceptance of technology. When applied to Level 2 systems, this means that drivers will only perceive the system as useful and easy to use if they experience it as controllable and reliable. Additionally, the concept of "cognitive overload" from [5]

broadens our understanding of how the complexity of driving tasks and driver intervention can affect physiological responses. Studies, such as those by [3], have shown that a highly fluctuating ratio between autonomous functions and manual intervention by drivers leads to increased physiological stress, which in turn can impair acceptance.

In summary, drivers' physiological responses to a Level 2 system are influenced by their perception of control and acceptance of the system. A deeper understanding of these aspects is crucial for the future optimization and improvement of autonomous driving systems, as well as for ensuring drivers' safety and well-being.

To further refine this understanding, a real-world driving study was conducted to assess the aforementioned aspects with drivers who had no prior experience with driving assistance systems above Level 0.

2. Method

A real-world driving study was designed for this purpose. A total of 19 people (9 female and 10 male; mean age M = 36,7; SD = 9,9) participated. It was important to recruit participants with no previous experience with Level 1, 2, or higher systems. After receiving an introduction to and explanation of a Level 2 system, the participants completed an approximately 50-minute drive in the vehicle.

The route was selected to ensure activation of the installed Level 2 function in the vehicle (BMW 5 Series). The route consisted of urban, rural, and highway sections (Fig. 1).

The system was activated when the following conditions were met: a vehicle was present in front, the vehicle was driving on a highway, there were visible lane markings, and the speed was below 60 km/h. The participants were instructed to follow a truck ahead of them on the highway for as long as possible.



Legend: Urban street, country road, and highway

Figure 1. Sections of the Test Drive Route

The recording of the respective system status and any system shutdown was ensured both by a camera pointed at the system display and by the eye-tracking system used (Dikablis 3.0). Since the use of different measurement systems can lead to time discrepancies, all data was recorded in the eye-tracking software (Dlab 3.56).

The test subjects' physiological parameters (skin conductance and heart rate) were recorded using an EXG measurement system from Becker Meditech. To ensure synchronization, this data was imported into the Dlab recording software of the eye tracking system as well.

In addition to the objective data, demographic data of the test subjects were collected, as well as, for each system drop, the subjective assessment of the criticality of the situation, system trust, and acceptance of the system used. An overall evaluation of the system in terms of comfort was also carried out after each trip.

This data was collected using a tablet with the Limesurvey questionnaire system. The test supervisor continuously recorded the data, conducting the survey immediately after each system drop. Each test subject conducted the survey at the turning point and at the end of the test drive on the tablet.

3. Evaluation and Results

The results are presented in separate sections. The first section presents and discusses the objective data. The second section deals with subjective data.

3.1. Physiological Reactions to System Drops

To evaluate the physiological reactions, we observed and statistically compared the 10 seconds before and after a system crash. This period was selected based on a previous literature analysis.

Examining the electrodermal activity (EDA) in millisiemens (mS) 10 seconds before and after each system drop revealed no significant differences in EDA before the drop (M = 9,64) compared to after the drop (M = 9,81). Therefore, even the first system drop does not lead to a significant change in EDA ($t(15) = -1{,}022$; p = n.s.), at least with regard to EDA (see Fig. 2).

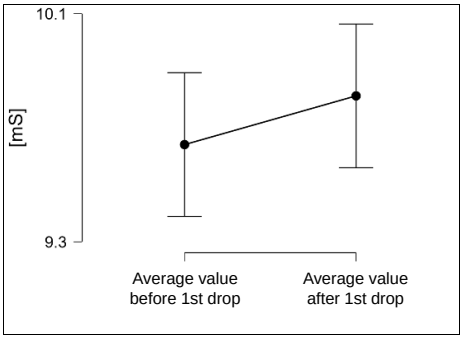


Figure 2. EDA mean value before and after the first system drop

Examining the heart rate (Fig. 3) one minute before and after the first system drop reveals a significant increase from 86,56 before the drop to 93,21 after the drop ($t(14) = -2{,}63$; $p = 0{,}020$).

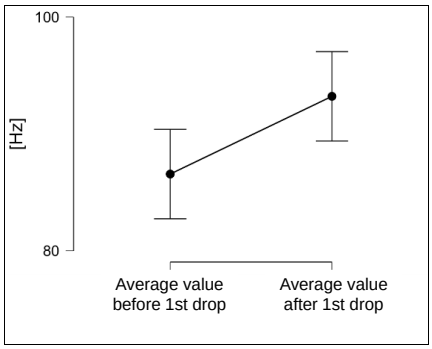


Figure 3. Heart Rate before and after the first system drop

3.2. Subjective Reactions to System Drops

As the number of system drops increases, the acceptance of the system significantly decreases (Fig. 4) ($F(2/32) = 8{,}41$; $p = 0{,}001$).

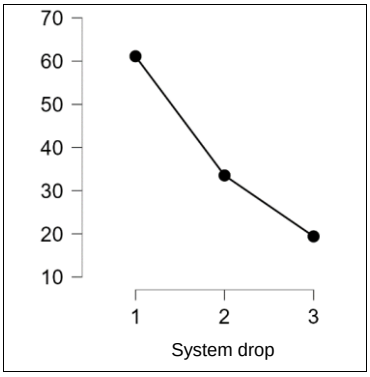


Figure 4. Acceptance after system drops

Similarly, the confidence in the Level 2 system has significantly decreased due to the increasing number of system drops (Figure 5) ($F(2/32) = 4{,}42$; $p = 0{,}020$).

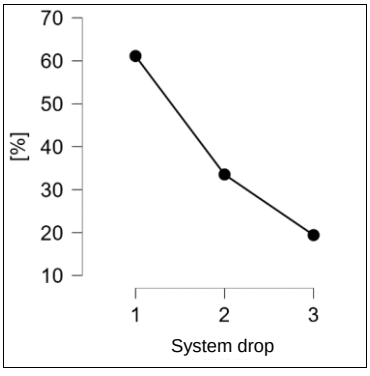


Figure 5. Confidence in Level 2 system after system drops

However, when considering the subjective perception of increased comfort provided by the system, it becomes apparent that, despite frequent system drops, the journey was perceived overall as comfortable (Fig. 7a). Additionally, most participants believed that the system shutdowns were justified. Furthermore, the system shutdowns were generally perceived as very safe (Fig. 7b). The system generally evoked positive emotions (Fig. 7c). Overall, the system received a good rating by the participants (Fig. 7d).

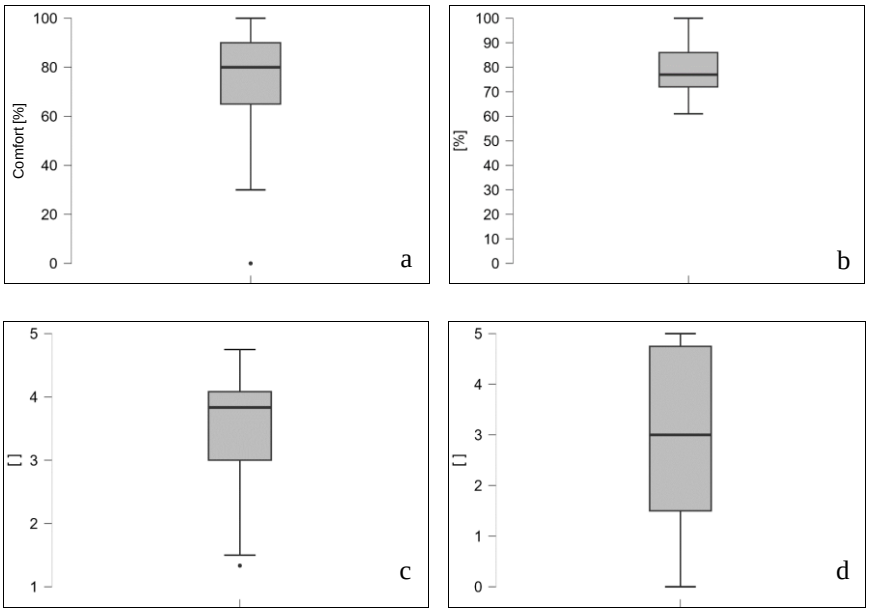


Figure 7. Perceived comfort while driving with Level 2 system (a), controllability during system drops (b), positive emotions (c) and overall evaluation of the system (d)

4. Conclusions

Overall, initial contact with a Level 2 system appears to lead to a physiological reaction. Heart rate values significantly increase, but this effect is not observed for skin conductance. Both parameters remain within a safe range.

Subjective perception of the system changes despite the many system drops. Although acceptance and confidence in the system decreased with an increasing number of drops, contrary to expectations, the overall evaluation and perceived usefulness of the system were not negatively impacted. Likewise, system drops were perceived as controllable.

Based on initial contact with Level 2 systems, it can be concluded that no overly strong physiological reactions are to be expected that could negatively impact road safety. Similarly, frequent system drops do not lead to an unfavorable evaluation of the system as a whole.

REFERENCES

1. *SAE* International Recommended Practice. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, SAE Standard J3016_201806, Revised June 2018, Issued January 2014, https://doi.org/10.4271/J3016_201806.

2. *Davis, F. D.* Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. Management Information Systems Research Center, University of Minnesota, 13(3), 319 – 340, 1989.

3. *Liu, X., Liao, Z.* Investigating the effects of the interaction between the automation level and the mode of in-tervention on driver performance. Transportation Research Part F: Traffic Psychology and Behaviour, 77, 128 – 142, 2021.

4. *Parasuraman, R. Sheridan, T. B. & Wickens, C. D.* A Model for Types and Levels of Human Interaction with Automobiles. IEEE Transactions on Systems, Man, and Cybernetics – Part A: System and Humans, 30(6), 286 – 297, 2000, DOI: 10.1109/3468.844354.

5. *Wickens, C. D.* Multiple resources and performance prediction. Theoretical Issues in Ergonomics Science, 9(5), 347 – 371, 2008.

ФИЗИОЛОГИЧНИ РЕАКЦИИ, ВЪЗПРИЕМАНЕ И ОЦЕНКА НА КОНТРОЛИРУЕМОСТТА НА СИСТЕМА ОТ НИВО 2 ОТ ШОФЬОРИ БЕЗ ОПИТ С ТАКАВА СИСТЕМА В РЕАЛНИ УСЛОВИЯ НА ДВИЖЕНИЕ

К. Райнпрехт[1], П. Целниг[2], Б. Христов[3]

Ключови думи: *системи за подпомагане на водача, SAE Ниво 2, физиологични реакции, електродермална активност, системна повреда, системен срив, проследяване на погледа, сърдечна честота, възприеман комфорт*

РЕЗЮМЕ

Системите от ниво SAE 2 за подпомагане на водача стават все по-разпространени на пазара и вече могат да бъдат намерени на достъпни цени при нови и употребявани автомобили. Въпреки това, към днешна дата се знае много малко за това как такива системи, които поемат надлъжното и страничното управление на автомобила, се възприемат от хора без опит със системи за подпомагане на водача и какви физиологични последици може да има една евентуална повреда в системата за съответния водач.

За да се отговори на тези въпроси, беше проведено проучване за шофиране в реални условия. В проучването бяха включени деветнадесет души (9 жени и 10 мъже; средна възраст M = 36,7 години, стандартно отклонение SD = 9,9 години) без опит със системи от ниво 1 или 2. След въведение и обяснение на система от Ниво 2 участниците в теста бяха помолени да извършат 50-минутно шофиране в превозното средство. Маршрутът

[1] Клаус Райнпрехт, д-р, Изследователски институт Инспекцио, Дизелщрасе 28, 85748 Гархинг до Мюнхен, e-mail: k.reinprecht@inspectio.de

[2] Петер Целниг, Изследователски институт Инспекцио, Дизелщрасе 28, 85748 Гархинг до Мюнхен, e-mail: p.zellnig@inspectio.de

[3] Борислав Христов, проф. д-р инж., факултет „Инженерни науки“, кат. „Пътно и транспортно инженерство“, Берлински университет за приложни науки (HTW Berlin), Вилхелминенхофщрасе 75A, 12459 Берлин, e-mail: Borislav.Hristov@HTW-Berlin.de

беше избран по начин, който осигурява активирането на функцията от Ниво 2, инсталирана в превозното средство (BMW Серия 5). Маршрутът се състоеше от три части: улица в града, извънградски двулентов път и автомагистрала.

За да се активира системата, трябваше да бъдат изпълнени следните условия: наличие на превозно средство отпред, движение по магистрала, видима маркировка на пътното платно и скорост под 60 km/h. Участниците в теста бяха инструктирани да следват движещ се камион по магистралата, доколкото това е възможно.

Резултатите показват значително намаляване на възприемането и доверието в системата от Ниво 2 с увеличаване на броя на прекъсванията на системата. Субективното възприятие за увеличаване на комфорта, осигурено от системата, обаче, показва, че въпреки честите прекъсвания, като цяло пътуването се възприема като комфортно. Освен това, повечето участници смятат, че прекъсванията на системата са били оправдани и са възприели пътуването като много безопасно и контролируемо.

Електродермалната активност (EDA) беше измерена с помощта на система за запис с два електрода. Този метод количествено измерва промените в проводимостта на кожата между двата електрода и служи като косвен показател за активността на вегетативната нервна система и физиологичното възбуждане. Анализът на EDA реакциите през 10-секундните интервали преди и след системна грешка не разкри статистически значими разлики. Тези резултати показват, че първата системна грешка не предизвиква измерима промяна в електродермалната активност и следователно не води до значима физиологична реакция.