SEMI-AUTONOMOUS ADVANCED PARKING ASSISTS: DO THEY REALLY HAVE TO BE LEARNED IF STEERING IS AUTOMATED?

Ingo Totzke, Susanne Jessberger, Dominik Mühlbacher, Hans-Peter Krüger
Center for Traffic Sciences (IZVW), University of Würzburg
Röntgenring 11, 97070 Würzburg, Germany
totzke@psychologie.uni-wuerzburg.de

ABSTRACT: A few studies have demonstrated positive effects of Advanced Parking As-sists (APA) on driver comfort and parking performance. Learning effects while handling the APA system and possible transfer effects on manual parking have not been discussed yet. In this study, N = 18 subjects parked parallel in a test area (26 manoeuvres) and in real traffic (9 manoeuvres). One half of the manoeuvres was done without the parking assist, one half with a semi-autonomous APA system which utilized automatic steering. The APA system did not control speed by accelerating or braking. Consistent with earlier studies, the APA system facilitates parking. Learning effects particularly ap-pear in glance behaviour and maximum velocity during the first parking motion. Using the APA over a large number of manoeuvres might influence parking without assistant: The more manoeuvres are done with the APA, the more often the drivers look into the display during manual parking.

1 INTRODUCTION

In recent years, an increased research and development activity in the field of Advanced Parking Assists (APA) could be seen. The range of APA systems varies from information systems (e.g. solely distance control or parking space measuring) to full-autonomous parking assists (automated steering and speed control; for an overview see [1]). Some of those sys-tems have already been introduced to the market, especially in the area of distance control. Nowadays, mainly ultrasonic systems inform the driver via acoustic sounds and/or visual displays about the distance to objects or to cars which restrict the parking space. At present, semi-autonomous APA systems for parallel parking represent the most advanced type of parking assist systems on the market. While steering is controlled by the system, the driver receives via displays a step-by-step instruction on how to move the vehicle (accelerating and braking).

Up to now, efficiency of APA systems has been analyzed empirically, for instance, respecting reduced operational demands for the driver during parallel parking or regarding an improved parking performance (e.g. [2] – [4]). However, learning effects while handling the APA sys-tem and possible transfer effects on manual parking have not been discussed so far. Accord-ing to the so-called "power law of practice" [5], it is expected that learning effects in handling the APA system particularly take place during the first manoeuvres while parking: The more often the driver parks with the APA system, the lower possible gains in learning are. Whereas the "power law of practice" has been demonstrated for learning processes concern-ing information systems in the vehicle (e.g. [6], [7]), no comparable studies have been pub-lished for Advanced Driving Assistant Systems (ADAS) yet. The present study's aim was to examine these learning effects while using a semi-autonomous APA system. It was assumed that possible learning effects particularly prevail during the first manoeuvres with the APA system.

2 METHOD

2.1 Semi-autonomous APA system

The APA system used in this study first supported the driver in finding a parking space by showing free spaces in a display placed on the upper central console. After stop-ping the car and changing into reverse, the APA system controlled the steering. The driver manoeuvred the car by using the systems instructions on the display regarding accelerating and breaking, while the system controlled the steering while parallel parking autonomously. The manoeuvre ended as soon as the pre-calculated parking position was reached. The systems' support continued when more forward and backward motions were necessary to reach the pre-calculated parking position. The driver could monitor the whole procedure on the display in the upper central console.

In addition, the car was fitted with a distance control system to check the distance to any neighbouring objects using ultrasonic sound (UPA, Ultrasonic Park Assist). Approximation to any object was indicated by an increasing signal until a constant alert indicated the minor distance of less than 30 cm to the other object.

2.2 Parking manoeuvres

The subjects had the task to park the car in parking spaces on a test area with and without the described semi-autonomous APA system, respectively. The same parking manoeuvres had to be done in real traffic. In the following, the results for the test area will only be consid-ered.

The first part of the study was done on a test area in an industrial area of Würzburg. A con-natural traffic situation was created (see Fig.1). Some cars formed six parking spaces on both sides of a lane, 5.5 m wide, approachable from both sides. The spaces were 2 m wide. One of the spaces was limited by a displaced car (see Fig.1 down right). In addition, road marking was added for a better identification of the lane and wooden beams were used as curb stones to mark the parking spaces.

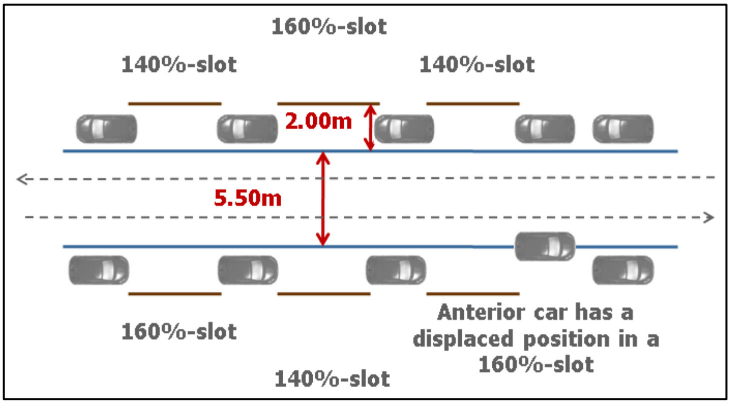


Fig.1. Schematic illustration of the study's design in the test area.

In allusion to Lee (2006), two different space sizes had been created:

- 140 % of the car's length (as the minimal space size, in which the APA system relia-bly identified a suiting parking space), or
- 160% of the car's length (as the minimal space size, in which the APA system could realize a one backward-motion parking position), respectively.

The length of the 140%-space was approx. 6.78 m, the one of the 160%-space approx. 7.74 m (the length of the test vehicle was 4.84 m). Parking into the 160%-space was judged as easier by the drivers compared to the 140%-space ("How strenuous was parking", m = 7.86, sd = 1.55 for 140%-space; m = 6.74, sd = 1.79 for 160%-space on a 16-point scale ranging from 0 = "not at all" to 15 = "very much", t-test for dependant samples: $t(53) = -7.724$, $p = .000$). In the following, results for selected manoeuvres in the 140%-spaces will be discussed only: four manoeuvres without APA (two manoeuvres of the training stage and one manoeu-vre of block 1 and block 2 each; see chapter "procedure") and three manoeuvres with APA (allocated to the whole part in the test area).

In some of the manoeuvres in the test area, staged situations were realized in which obsta-cles were positioned in the vehicle's pathway (e.g. a tethered toy coupe was pulled into way of the car while backing up; a post was placed within the parking space by an on-road ex-perimenter). These obstacles should stand for passers-by or any not detected objects (for further information and results see [4]).

2.3 Glance behaviour analysis

The glance behaviour of subjects was measured by means of the head-mounted measure-ment device "Dikablis". In the head unit of that device two cameras have been installed, the one directed on the environment, the other on the left eye of the subject. Through superim-position of both camera pictures the glance behaviour of the subjects could be specified.

The superimposed videos have been coded manually. For this purpose five areas of interest (AOI) were defined:

1. front windshield
2. mirrors
3. front side windows
4. display
5. rear windows

For each AOI the following parameters were calculated:

- duration of glances (mean, median, maximum)
- glance direction („no glance into AOI“ vs. „minimum one glance into AOI“)
- relative frequency of AOI during the whole parking manoeuvre
- In the following, the glance behaviour of the driver during the first backward motion will be discussed exclusively. This is because the driver leaves the flowing traffic and might get in contact with obstacles in the parking space. Therefore, particularly the first backward motion addresses safety-relevant aspects while parking. The first backward motion starts with a stop after passing a free parking space and ends with a halt at the end of the first backward mo-tion.

2.4 Procedure

The experimental session included the following stages:

(1) training stage in a test area (8 manoeuvres)
(2) block 1 and block 2 in a test area (9 manoeuvres each)
(3) public traffic (9 manoeuvres)

The session started in the test area with the installation of the glance behaviour measuring device. The subject was not given a detailed explanation of the functionality of the APA sys-tem. Instead, there was only a short instruction designed to be similar to a “car rental situa-tion”. Thereafter, the subject gained experience in handling the car and the APA system by performing 4 parking manoeuvres without as well as with the APA system (“training stage”). During these manoeuvres the subject had to acquaint her-/himself with realizing the system’s functionality. After the training stage, detailed system instructions were given to the driver.

In the main part of the session (“block 1” and “block 2”), the driver had to perform 18 ma-noeuvres (9 manoeuvres with and also 9 manoeuvres without the semi-autonomous APA system) in the test area. After 9 manoeuvres each, the subjects took a break during which they could put off the glance behaviour measuring device.

In public traffic, the driver had to perform 9 parking manoeuvres, nearly half of the manoeu-vres with and without the APA system each.

After each manoeuvre, the subjects were asked for their judgements concerning workload, parking performance and (if applicable) problems with handling the vehicle or the APA sys-tem. After each stage of the session, the subjects had to answer a questionnaire and the in-vehicle experimenter gave judgements about the driver’s performance in the preceding stage (e.g. concerning appropriate reaction and safe reaction on the APA system). Additionally, there was a detailed survey done by the experimenter at the end of the session.

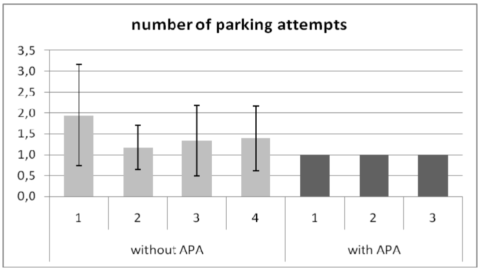
The study was conducted by an in-vehicle experimenter (who sat behind the driver and con-ducted the inquiries, counted driver’s errors etc.) and an on-road experimenter (who realized the staged situations, counted driver’s errors etc.). Several Can BUS data were recorded (e.g. velocity). Altogether, each subject performed 35 parking manoeuvres which is a high number compared to naturalistic driving. The whole session lasted approximately 4 hours.

2.5 Sample

Altogether N = 18 subjects (9 male and 9 female) between 19 and 72 years of age (m = 40.3, sd = 21.9) participated in the study. The subjects were members of the test driver panel of the Würzburg Institute for Traffic Sciences (WIVW). The groups consisted of drivers, of who one half estimated their capabilities in parallel parking as “good” and the other half respec-tively as “poor”. On the other hand one third of the sample represented a younger age (19-20 years), another third a middle age (25-49 years) and the last third an older age group (65-72 years). The needed information was ascertained by online questionnaires prior to the test. The subjects were granted an expense allowance for their participation.

3 RESULTS

With the APA system, nearly all parking attempts are successful and the number of parking motions is smaller than with parking without APA (see Fig.2). These results reflect the func-tionality of the APA system. Therefore, no learning effects for handling the APA system can be seen (number of parking attempts with APA: inferential statistics cannot be applied as no variation is found; number of parking motions wit APA: one-factor ANOVA for within-factor “manoeuvre”, $F(2,32) = 0.399$, $p = .674$, eta2 = .024). Compared with this, the drivers gain experience in parallel parking itself while parking without APA: The number of parking at-tempts as well as the number of parking motions (one-factor ANOVA for within-factor “ma-noeuvre”, $F(3,48) = 2.460$, $p = .074$, eta2 = .133; $F(2,51) = 2.918$, $p = .043$, eta2 = .146, re-spectively) diminish with growing experience in handling the vehicle during manual parking, particular in direct comparison of the first and second manoeuvre during manual parking with the test vehicle.



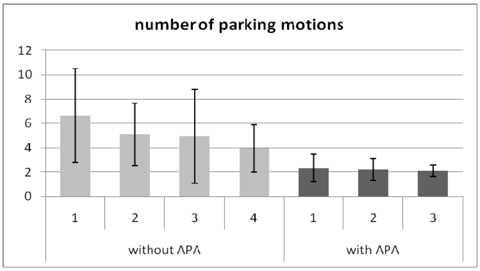


Fig.2. Mean number of parking attempts (left) and mean number of parking motions (right).

Pictured is the mean with standard deviation.

The maximum velocity during the first parking motion is reduced with growing experience in handling the APA system (one-factor ANOVA for within-factor "manoeuvre", $F(2,34) = 3.454$, $p = .043$, eta2 = .169; see Fig.3). Compared with this, the distribution of velocity largely re-mains constant. As a result, there is no learning effect on the duration of the whole parking manoeuvre.

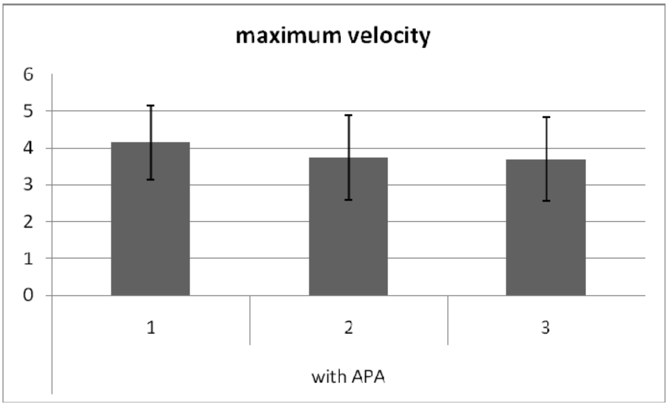


Fig.3. Mean maximum velocity [in km/h] during the first parking motion. Pictured is the mean with standard deviation.

According to the observations of the in-vehicle experimenter after each stage of the experi-mental session, the drivers react more pertinently and safely to the APA system with growing practice (one-factor ANOVAs for within-factor "manoeuvre"; appropriate reaction: $F(2,34) = 9.677$, $p = .000$, eta2 = .363; safe reaction: $F(2,34) = 23.415$, $p = .000$, eta2 = .579; see Fig.4). These learning gains appear between the training stage and block 1, in particular.

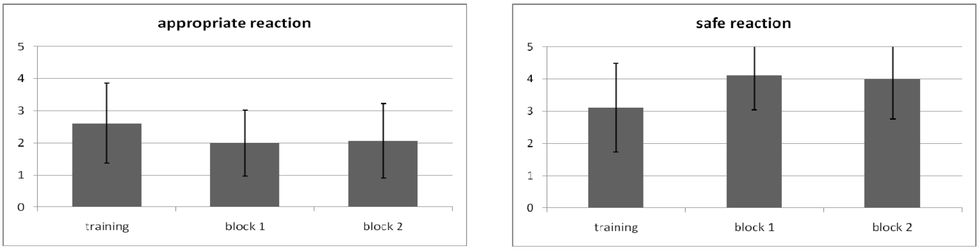


Fig.4. Mean judgements of in-vehicle experimenter concerning appropriate reaction (left) and safe reaction (right) on the APA system in the preceding stage of the session Pictured is the mean with standard deviation.

Additionally, the drivers were asked immediately after a parking manoeuvre to give judge-ments on a 15-point scale concerning perceived workload and safety while parking (see Fig.5). In the course of the session drivers' answers on the question "How strenuous was parking" (perceived workload, see Fig.5 on the left) do not change neither for manual parking (one-factor ANOVA for within-factor "manoeuvre", $F(3,51) = 1.823$, $p = .155$, eta2 = .097) nor for assisted parking with APA (one-factor ANOVA for within-factor "manoeuvre", $F(2,32) = 0.775$, $p = .469$, eta2 = .046). Overall, reported workload of the driver appears to be of me-dium height.

Similarly, drivers' judgements concerning "How confident did you feel during parking?" (per-ceived safety, see Fig.5 on the right) do not vary significantly over time while parking with APA (one-factor ANOVA for within-factor "manoeuvre", $F(2,32) = 1.389$, $p = .264$, eta2 = .080): The drivers feel largely confident during parking with APA. However, learning effects apply for manual parking concerning reported safety (one-factor ANOVA for within-factor "manoeuvre", $F(3,51) = 3.318$, $p = .027$, eta2 = .163): Especially in the first non-assisted parking manoeuvre drivers feel less safe compared to the following parking manoeuvres.

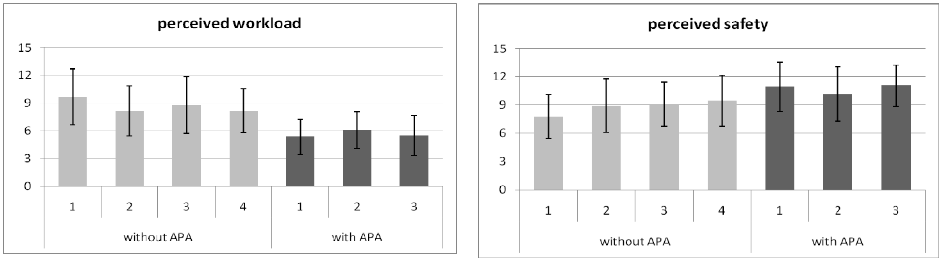


Fig.5. Drivers answers on the question" How strenuous was parking" (left) and "How confident did you feel during parking" (right). Pictured is the mean with standard deviation.

Learning effects are visible in the glance behaviour during the first parking motion with APA (see Fig.6): The more experience the driver has with handling the APA system, the less vis-ual attention is used to monitor the system's display. For other "areas-of-interest" (e.g. wind-shield, windows, backwards, mirrors) no systematic learning effects can be proven. For manual parking, no systematic changes over the course of the session can be shown except for looking backwards.

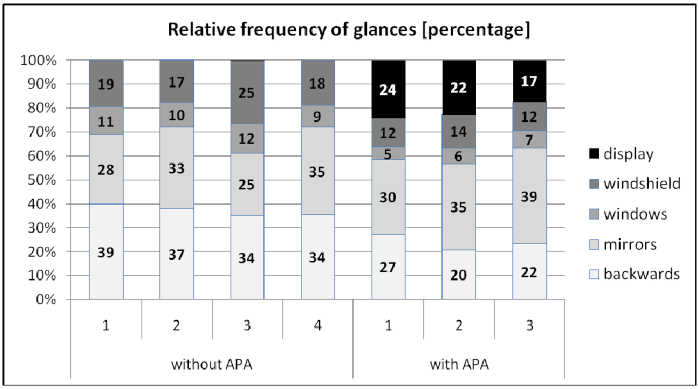


Fig.6. Relative frequency of glances [in percentage] into AOI during the first parking motion of manoeuvres with and without the APA system, respectively.

Surprisingly, with growing practice more drivers look at least once into the system's display while parking without APA, even though this display is deactivated while parking without APA (seeFig.7). During assisted parking, nearly all subjects look at least once into the display during the first parking motion. In this case, no learning effect can be shown: Using the APA system needs at least one glance into the system's display.

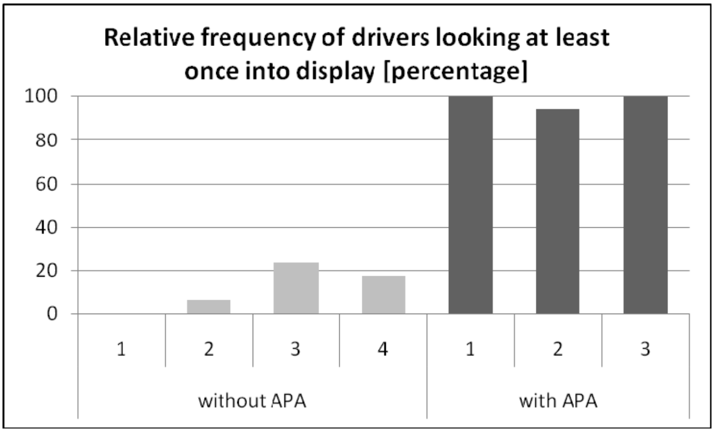


Fig.7. Relative frequency of drivers who look at least once into the system's display [in percentage] during the first parking motion with and without the APA system, respectively

4 CONCLUSIONS

To sum up, the lower numbers of parking attempts and parking motions as well as the positive judgements of the drivers about the APA system indicate that the usage of the parking assistant facilitates parking. These results are consistent with published studies which have shown positive effects of APA systems respecting operational demands for the driver during parallel parking or regarding an improved parking performance (e.g. [2] – [4]). Nevertheless, the expansion of automation (for instance the launch of full-autonomous APA systems) should be handled with care: Higher automation levels of APA systems might go along with a decrease of the driver's attention to the environment, as, for instance, the increased probability of dangerous traffic situations [4]. These dangerous situations might mainly occur when the system reaches its limits (e.g. moving obstacles like passers-by or objects hard to detect due to size or design like posts or bicycles).

Learning effects appear in particular in glance behaviour and maximum velocity during the first parking motion as well as in drivers' reaction to the APA system: The more experience the driver has with handling the system, the less visual attention is used to monitor the system's display, the lower is maximum velocity and the drivers react more appropriately and safely to the APA system. No systematic learning effects can be found in drivers' judgements concerning their perceived workload and perceived safety. Moreover, the results largely con-firm the assumptions made by the "power law of practice" [5]: If learning effects appear, these are dominant in the first part of the session. Therefore, this law can be applied to learning effects while handling an APA system (as an example of an ADAS).

However, the learning effects in handling the APA system might even influence the glance behaviour during parallel parking without a parking assistant: The more manoeuvres are done with the APA system, the more often the drivers look at least once into the display while parking without the APA system, even though this display is deactivated. Some drivers seem to have introduced the system's display into their gaze pattern during parallel parking even in manual parking. It is questionable whether this carry-over effect will hold on after a larger number of manoeuvres without an APA system. Nevertheless, unintended carry-over effects respecting glance behaviour have to be considered in further studies.

5 REFERENCES

[1] Lambert, G., Kirchner, A., and Hüger, P.: 'Parkassistenzsysteme. Technologien von heute und morgen', in VDI-Gesellschaft Fahrzeug- und Verkehrstechnik (Ed.): 'Integrierte Sicherheit und Fahrerassistenzsysteme' (VDI-Verlag, 2008, VDI-Berichte Nr. 2048)

[2] Doisl, C.: 'Systemergonomische Analyse von Anzeige- und Bedienkonzepten zur Unter-stützung des Parkvorgangs'. PhD thesis, TU München, 2007

[3] Lee, W.C.: 'Beiträge zur Entwicklung eines Fahrerassistenz-Systems für Einpark-vorgänge'. PhD thesis, TU Illmenau, 2006

[4] Totzke, I., Mühlbacher, D., and Krüger, H.-P.: ‘Semi-autonomous Advanced Parking As-sist – a source of drivers’ distraction?’, in D. de Waard, A. Axelsson, M. Berglund, B. Peters, and C. Weikert (Eds.): ‘Human Factors: A system view of human, technology and organisation) (Shaker Publishing, 2010), pp. 1-10

[5] Newell, A., and Rosenbloom, A.: ‘Mechanisms of skill acquisition and the Law of Practice’, in Anderson, J.R. (Ed.): ‘Cognitive Skills and their Acquisition’ (Erlbaum, 1981), pp. 1-55

[6] Jahn, G., Oehme, A., Rösler, D., and Krems, J. F.: ‘Kompetenzerwerb im Umgang mit Fahrerinformationssystemen‘, in Bundesanstalt für Straßenwesen (Ed.): ‘Berichte der Bundesanstalt für Straßenwesen‘ (Wirtschaftsverlag NW, 2004, Fahrzeugtechnik Heft F 47)

[7] Totzke, I., Krüger, H.-P., Hofmann, M., Meilinger, T., Rauch, N., and Schmidt, G.: ‘Kom-petenzerwerb für Informationssysteme - Einfluss des Lernprozesses auf die Interaktion mit Fahrerinformationssystemen‘ (Berthold Druck, 2004, FAT-Schriftenreihe Band 184)