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Drivers' acceptance and behavioural adaptation of Advanced Driver Assistance Systems

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1. Background

- According to the United Nations Economic Commission for Europe (UNECE, 2015), in 2013, over a **million car accidents** involving personal injury were reported in Europe, **45%** of which happened between **two or more vehicles**.
- A common cause of rear-end collisions is **driver inattention**; in a 100-car naturalistic study, driver distraction was present in 87% of rear-end crashes and 78% of all crashes (Coelingh, Jakobsson, Lind, & Lindman, 2007; Klauer, Neale, Dingus, Ramsey, & Sudweeks, 2006; Lee, Llaneras, Klauer, & Sudweek, 2007).
- Some advanced driver assistance systems (ADAS) were developed to prevent rear-end crashes or mitigate their impact by monitoring the distance from the vehicle in front and warning the driver of an imminent collision.



1. Background

- Jermakian (2011) estimates that **Forward Collision Warning** could **prevent up to 20%** of all crashes (on the basis of the US NASS General Estimates System and Fatality Analysis Reporting System 2004-2008 data).
- On the other hand, because of behavioural adaption, as is well known from previous studies (e.g. Smiley, 2000), these estimates might be **quite overestimated**.



1. Background

- Neither of the **systems relieves the driver completely from the need to pay attention** to the traffic ahead.
- ADAS are not perfect: some system versions do not operate at velocities lower than 30 km/h or do not detect motorcycles, bicycles, pedestrians, or animals on the road, as well as stopped cars or stationary objects such as roundabouts. Because of sensor imperfections, ACC can also “lock onto” an object in the adjacent lane while overtaking or in highly curved road segments, and the system does not perform well in heavy rain, snow, or fog.
- Therefore, the driver must always be prepared to resume control over the **vehicle** (Burnett & Diels, 2014; Larsson, 2012; Sullivan, Flannagan, Pradhan, & Bao, 2016).
- The possible risk in terms of traffic safety is the **much longer reaction time** (when the driver resumes driving) than the “normal” reaction time when a driver is driving (Schleicher & Gelau, 2011).



1. Background

- Although the above-mentioned limitations are usually described in the **user's manual**, this does not necessarily mean that drivers are aware of them. In a survey of 370 ACC owners, although 67% claimed they learned to use the system by reading the manual, 72% did not know about any limitations or manufacturer's warnings about ACC (Jenness, Lerner, Mazor, Osberg, & Tefft, 2008).
- Research suggests that drivers' awareness of potential problems with ACC or FCW increases over time, but it is crucial that they encounter them directly while driving, at least occasionally. Otherwise, drivers **forget that these limitations exist** and they might display unrealistic over-reliance on the systems (Beggiato & Krems, 2013; Beggiato, Pereira, Petzoldt, & Krems, 2015; Jenness et al., 2008; Larsson, 2012).
- As for user **acceptance**, drivers who were not informed beforehand about situations in which the system is not fully operational showed **more negative affects after** they encountered them in a field test, and their trust in the system decreased over time, without recovery (Beggiato & Krems, 2013).



2. Method

The **aim** of the present research was to establish among a sample of Czech drivers:

- what **information** they have about the systems,
- **acceptance** of the systems,
- how ADAS owners **acquired** information about the systems and which methods they would prefer for **learning** about the systems' **capabilities and limitations**.



2. Method

ADAS under study:

- ACC – adaptive cruise control (“ACC monitors the distance from the vehicle ahead and maintains the set distance and/or speed.”)
- FCW – forward collision warning (“FCW monitors the distance from the vehicle ahead and the speed of approach; in the event of imminent danger, it alerts the driver and/or activates the brakes.”)
- LDW – lane departure warning (“LDW tracks the vehicle’s position within a lane; in the event of leaving the lane without a turn signal, it alerts the driver and/or corrects the movement.”)
- Blind spot monitoring (“Alerts the driver if a vehicle in the adjacent lane is detected in the blind spot of the car.”)
- Driver drowsiness detection system (“Monitors the driver’s behaviour and alerts the driver to take a break.”)
- Traffic sign recognition system (“Recognizes traffic signs and displays them on the display or the navigation system’s monitor.”)
- Automatic high beams (“High beams are automatically turned on/off, so that other drivers are not blinded.”)

In this presentation we will focus on ACC and FCW only.



2. Method

2. 1. Interviews

In-depth semi-structured interviews were used in order to understand how ADAS owners learned about the systems and their functions, if they had encountered any problematic situations while using the systems, and what instructional methods they would prefer for learning about the systems' abilities and limitations. The following topics were discussed:

1. Initial gaining of information
2. Learning about system control
3. Preferred knowledge and instructional methods
4. On-road experience of the system
5. User satisfaction



2. Method

2. 1. Interviews

The interviews were analyzed using qualitative content analysis, categorizing the statements regarding each topic, and identifying recurring answers (e.g. learning sources, preferred learning methods, etc.)

Participants were selected on the basis of the following criteria using quota sampling (Llaneras, 2006), so that:

1. they had experience of at least one of the ADAS under study (ACC, FCW, Lane departure warning, Intelligent light assist, Blind spot monitoring, Road sign assist, Driver alert);
2. approximately 1/3 of the sample were women;
3. 30% of the sample were drivers less than 30 years old, 60% were between 30 and 65 years old, and 1% were over 65 years old (seniors).

Altogether, 38 drivers were interviewed. Period March-August, 2016.



2. Method

2.2 Online questionnaire

The questionnaire was distributed during November 2016-April 2017 in the form of:

- a) an online survey using the snowball method; altogether, 435 participants filled out the online survey;
- b) in electronic form, the questionnaire was also distributed as a part of a larger testing at the Škoda Auto research centre and 54 completed questionnaires were collected;
- c) in printed form, the questionnaire was distributed at a trade fair for electronics and automation, and respondents were promised a small reward (consisting mostly of stationery) for filling out the questionnaire; 40 questionnaires were collected in this way and transcribed into an electronic form.

In total, 526 questionnaires were analyzed further, using the means of descriptive univariate and bivariate statistics.



3. Results

3.1. Interviews

Mostly, the respondents **did not learn about the systems' existence earlier** than upon buying the car, when the dealer provided the initial information.

If drivers knew about the systems, they read about them previously on the **internet or in magazines**. These were often men who indicated a long-term interest in cars and automotive technologies.

In some cases drivers first experienced the system in a **company car**.

In 3 cases, for ACC, the respondents indicated they did not know about the system until they **accidentally turned it on** while driving; this happened only once with FCW.

Yet when the question was rephrased to *“How did you learn about the systems' function”*, almost all the drivers agreed they learned about it via **on-road experience**.



3. Results

3.1. Interviews

Therefore, we asked about the **drivers' motivation to purchase** the respective systems. The most frequent answers for **FCW** were the fact that the system was **“already in the car”** or came as part of a **“bargain package”**.

For **ACC**, the responses were similar, although a substantial number of respondents said that **“they simply wanted the system”**, without further explanation. Also, **“safety”** was given as a reason more often for ACC than FCW.

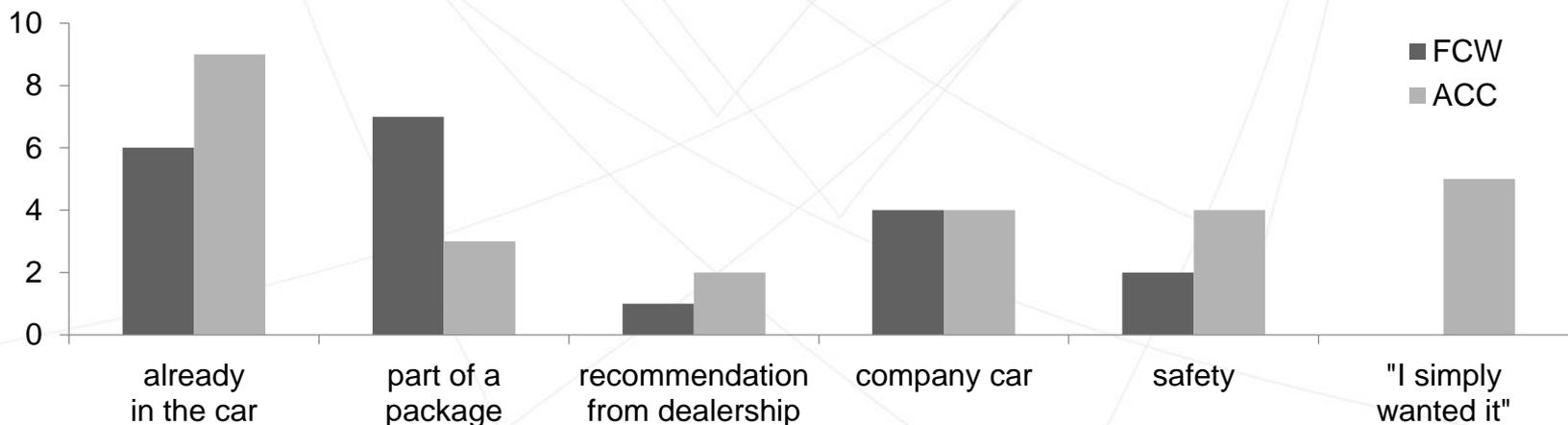


Fig. 1 Reasons for purchase (absolute frequencies; participants could mention more than one reason)



3. Results

3.1. Interviews

Considering the kind of **information the drivers would have liked to receive prior to buying** the system, the respondents emphasized the limitations of the system:

- “I would have liked to know about the system’s drawbacks, because if you claim something to be ‘intelligent’, you get the impression it can do anything.”
- “I would have liked to know that if the sensor is obstructed by, say, snow, it stops working.”
- “No one told me it only works within certain speed limits.”
- “I’d like to know if the FCW reacts to pedestrians as well.”

Most of the drivers stressed the importance of a **“well-informed dealer”** and recommended taking a demonstration drive:

- “Nowadays, you can find a ton of information, reviews on the internet, but to try to drive a car with the system is a completely different experience.”
- “The dealer can influence you a lot if he seems to know about the systems and he’s willing to show you. That’s the best thing he can do. Otherwise, he can put you off.”

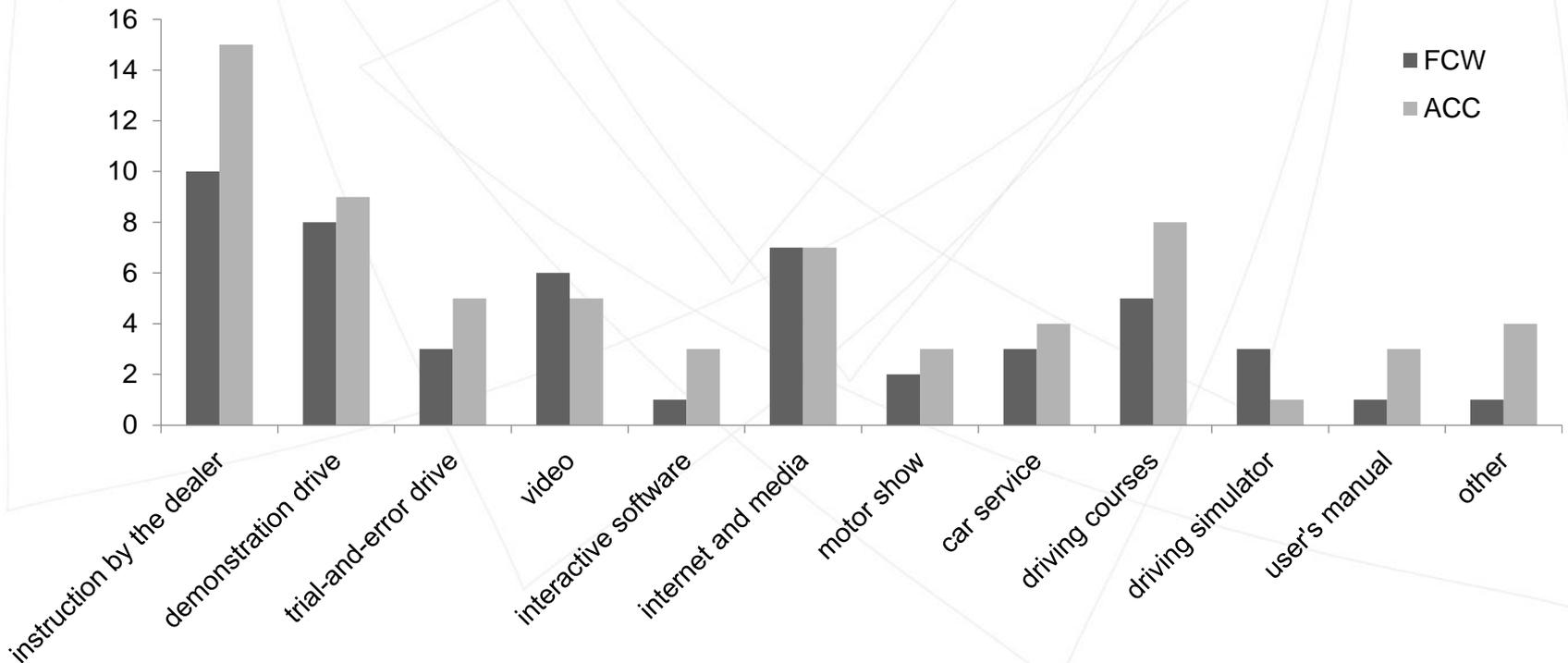


The figure summarizes the preferred/suggested instructional methods for learning about the systems' existence, functions, limitations, and control.

3. Results

3.1. Interviews

The dealer should then focus on the **“real behaviour”** of the system, e.g. explain the **limitations** and elaborate on traffic situations in which the system's functioning might be limited, and subsequently take the potential buyer **for a test drive**, during which, ideally, some of these situations are experienced.





3. Results

3.1. Interviews

When asked specifically if the systems should be taught in **driving schools**, about a half of each system's owners (48% for FCW and 50% for ACC) replied "yes", with 3 owners of each system adding "but only theoretically".

Another 20-30% of the respondents said they couldn't give a definite answer. The main reasons why driving schools **should not be teaching about or how to use** the systems, according to the respondents, were that **novice drivers should learn to rely on themselves** rather than on systems which are, at present, "not that common" and considered to be "something extra".



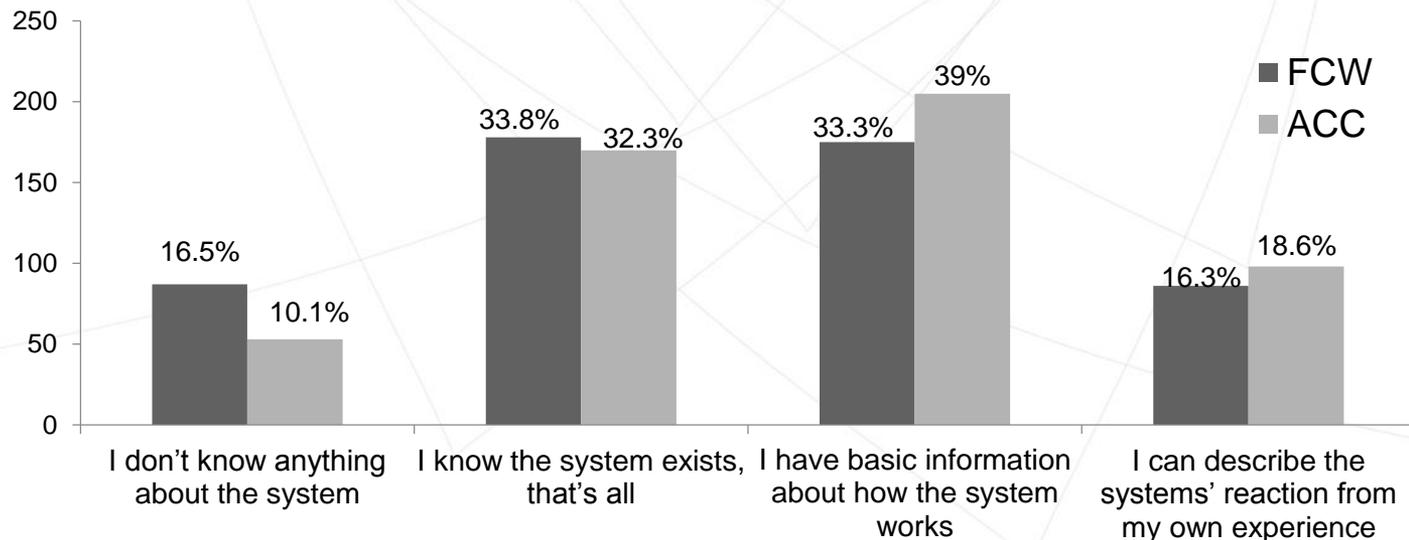
3. Results

3.2 Online questionnaire

Information about ADAS and how to get it:

About **half of the drivers** indicated they either **don't know anything** about the systems under study or they just know the systems exist; generally, the (perceived) amount of information was slightly higher for ACC than FCW.

At the same time, **most of the respondents did not have** personal experience of the systems; again, the amount of experience was slightly higher for ACC.





3. Results

3. 2. Online questionnaire

Information about ADAS and how to get it:

When asked about ADAS in general, the drivers mostly **did not believe using the systems relieves them from the need to pay attention** or that the systems can take complete control over the vehicle.

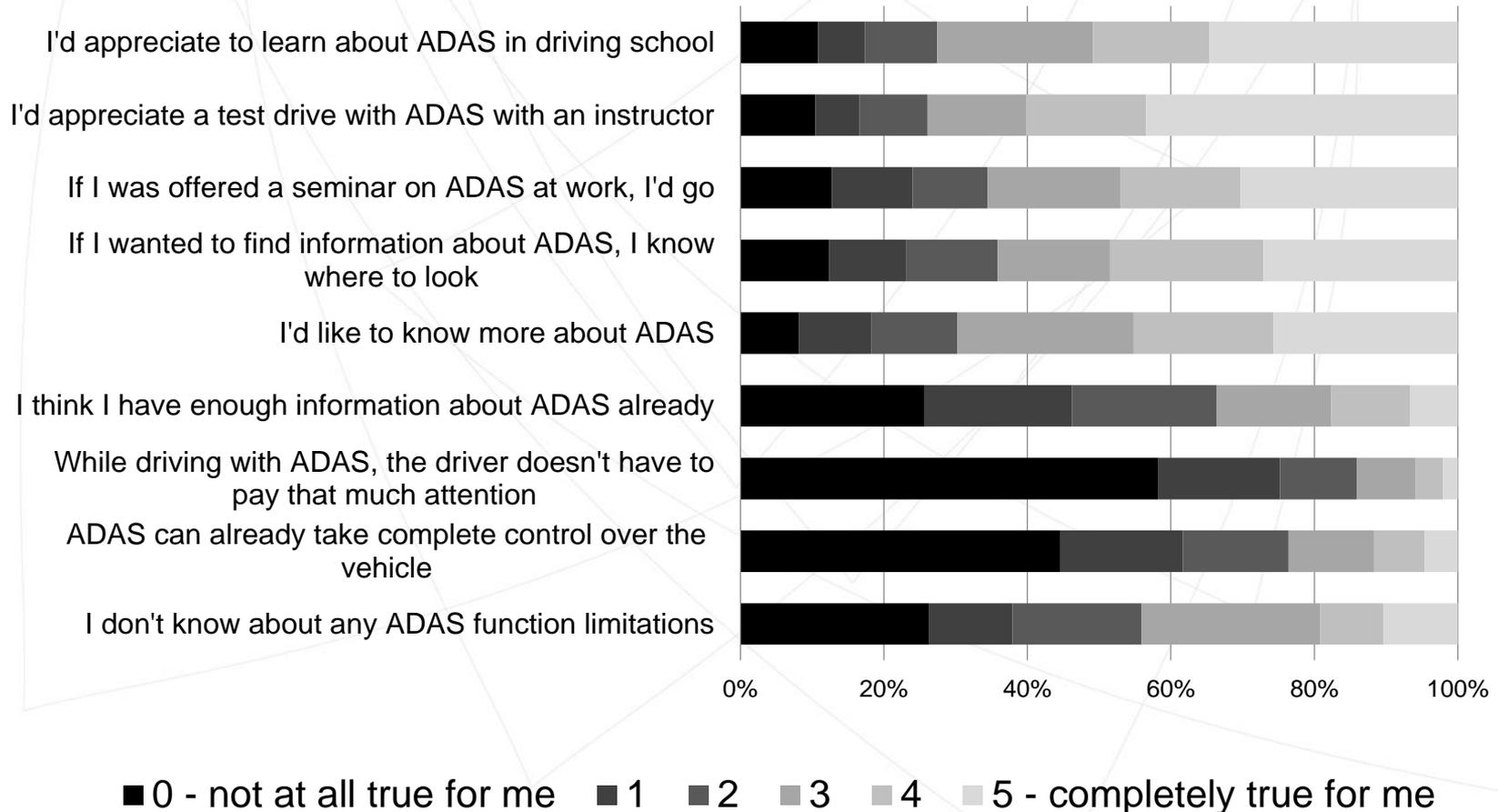
The drivers suggested they would **like to know more about ADAS**.

More than half of the respondents agreed they would appreciate learning about the **systems at a driving school, taking a test drive** with an instructor, or attending a **seminar at work**.



3. Results

3. 2. Online questionnaire





3. Results

3. 2. Online questionnaire

As for the **acceptance of ADAS:**

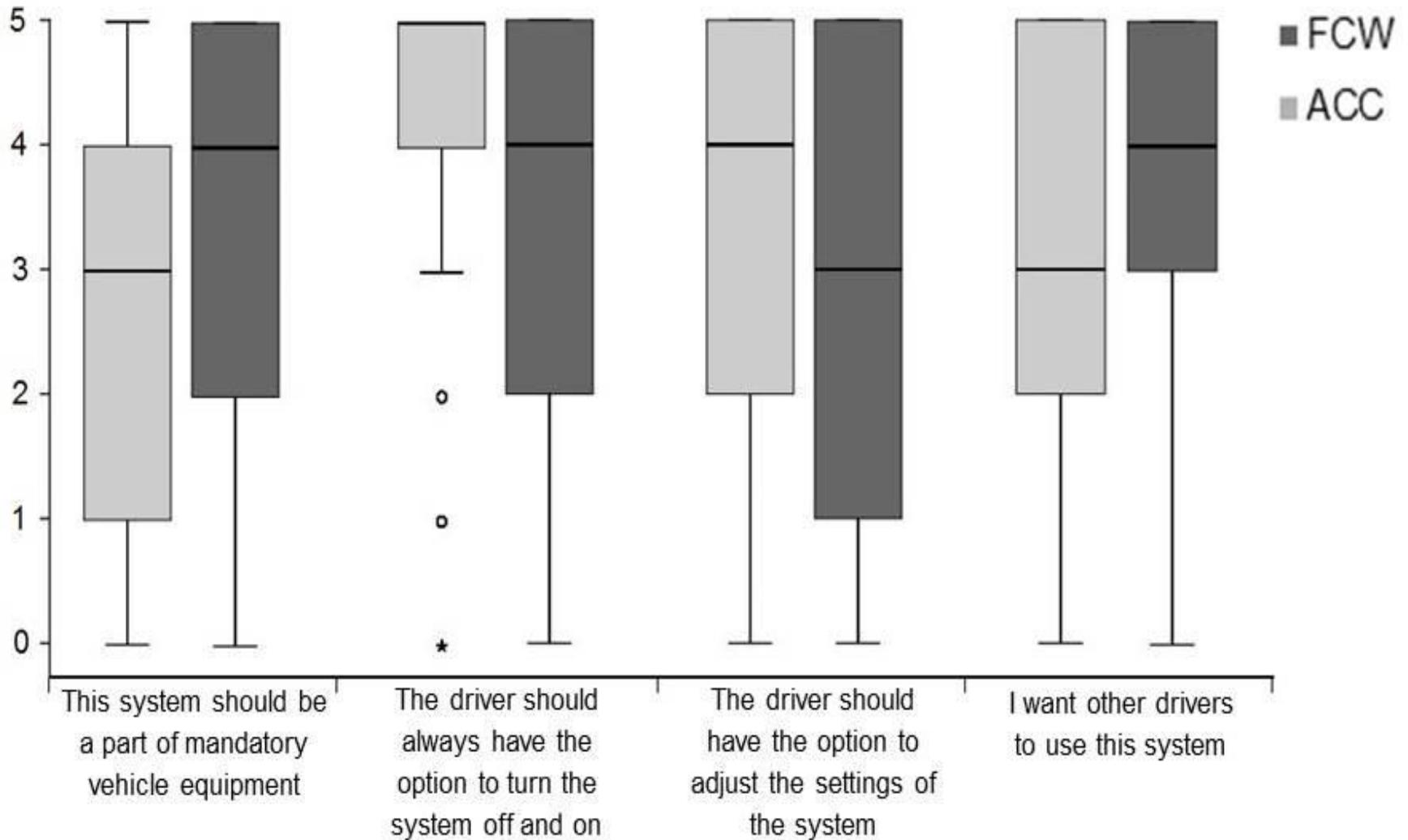
For **FCW**, as compared to ACC, the ratings were **higher** on “*I want other drivers to use the system*”, but a diversity of opinions still existed on whether the system should be a part of **mandatory** vehicle equipment and, mostly, if the driver should be able to **adjust the settings of the system**.

On the other hand, for **ACC**, the respondents were almost unanimous that the driver should always have the **option to turn the system on and off** and they didn't perceive the system as so necessary that it should become mandatory.

Overall, the drivers tended towards higher rankings on all four of the items, indicating **that they don't reject the systems in general**, but they would probably like to **retain the option to decide if they want to use the system and adjust its specific settings**.



6-point Likert scale (0 – “not at all true for me”; 5 – “completely true for me)





3. Results

3. 2. Online questionnaire

As for the **acceptance of ADAS**:

As a second way to assess acceptance, we asked the drivers to indicate for each system whether they **would want it in their car and how much money** they would be willing to pay for it.

Most drivers would want FCW in their cars, mainly for **safety purposes**, as compared to ACC, which is perceived slightly more as a **comfort-enhancing than a safety system** – although this category was also chosen by approximately a third of the respondents.

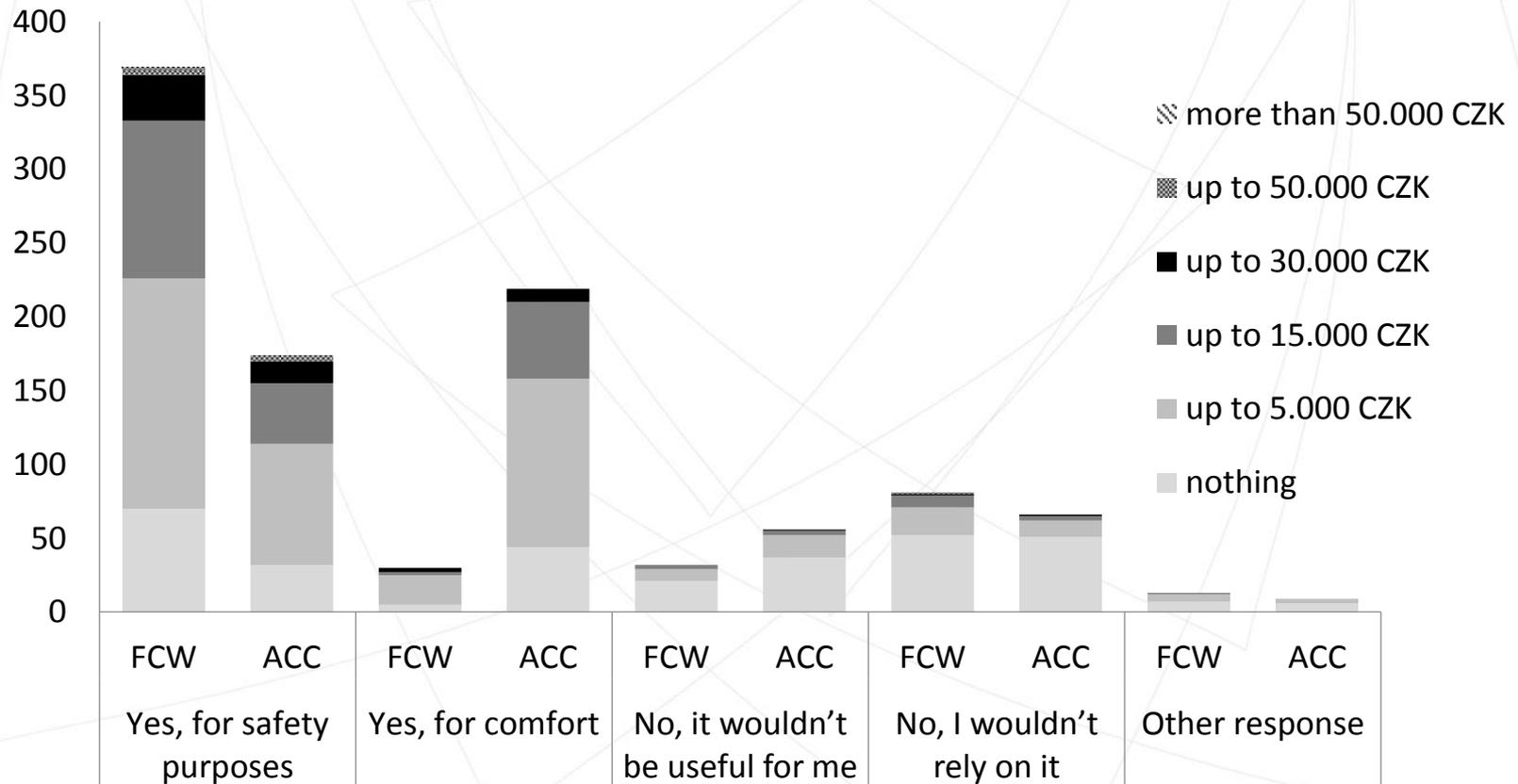
Generally, the drivers are **not willing to spend much extra money on either of the ADAS under study**, but the maximum amounts increase if the system is perceived as **safety-enhancing**.

On the basis of the responses, it can be concluded that the drivers show a **relatively high degree of acceptance of the systems**, but they hesitate to spend too much money on them and some would still not trust the systems completely.



3. Results

3. 2. Online questionnaire





3. Results

3. 2. Online questionnaire

Associations between **acceptance, amount of information, and experience** of ADAS were also investigated using the Pearson's Chi-squared test.

A substantial number of drivers who **don't have any information or experience of the systems tend not to buy them** because they **would not rely on them**. For **ACC**, they also tend to purchase the system for safety purposes, not just for comfort.

On the other hand, drivers **with their own experience of the systems** generally tend to buy them again, although for **ACC**, they claim to see a **safety benefit**, as well as comfort enhancement.

	Chi-square	df	p
ACC info	48,814	12	< ,001
ACC experience	43,109	12	< ,001
FCW info	20,061	12	,066
FCW experience	25,34	12	,013



4. Discussion

- Overall, the respondents emphasized **practical experience of the systems**. Even with the videos and interactive software, some expressed the desire to have these built in or **available to play directly on the car computer**, in order for the drivers to be able to try the functions immediately after.
- The videos (or “learning programs”) should explain the basics about system control and then **show different situations in which the system might or might not** be useful, depending on the specific **limitations**.
- Also, system **limitations** are something the drivers usually had **to experience on their own**, without previous knowledge. They often recalled encountering specific problematic situations (e.g. the system activity above/below certain speed limits or in worsened weather conditions) as **surprising** and something they had to adjust their behaviour to.



4. Discussion

- This finding addresses two issues previously discussed in the existing literature: First, if the drivers don't know about the **limitations of FCW and ACC beforehand** and they don't experience them on the road either, they might have **false, potentially dangerous expectations concerning the systems' performance**.
- And second, encountering unexpected situations of reduced system performance might **lower acceptance of FCW and ACC in general**, or even discourage the driver from using the systems at all.
- Therefore, **timely education** of drivers seems appropriate. It is not advisable to rely on the drivers reading the user's manual, as a large part of them admit to not reading it at all or just partly, possibly skipping the manufacturer's warnings.
- It is crucial to **educate car dealers** (as a primary source of information for a substantial proportion of FCW and ACC owners), encouraging them to disclose the **limitations** of the systems as well.
- Also, **in driving schools**, at least theoretical lessons about advanced driver assistance systems could be included, in order for (again, at least) novice drivers to gain some awareness of the available systems, even if they are not particularly interested in automotive technologies themselves.



5. Implications and conclusions

1. As knowledge about ADAS among drivers is rather low, large-scale learning measures should be adopted. The main focus should be on basic information about the system and its limitations.
2. It is not possible (and partly a matter of passing the buck) to count on drivers reading the information in the user's manual.
3. Suggested ways of informing drivers: lessons in driving schools, well-educated car dealers, short and interactive messages (e.g. videos) available in the car.
4. Education should be as practical as possible; ideally, test drives where the limitations of the system can be experienced.
5. Education should stress the safety benefits of ADAS.



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