SYSTEM LIMITATION EXPERIENCES BY SWEDISH DRIVERS USING ACC AND LKA

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ABSTRACT

For many ADAS to reach its full safety potential they need to be activated and used by its drivers. There are thus several known (technical) limitations that could, as indicated by research, potentially affect the perception and use of the ADAS. This paper explores limitations as experienced by users for the lateral assistance systems Adaptive Cruise control (ACC) and Lane Keep assist (LKA). The paper partly reports on a larger online survey launched (n=1822) in 2021 aimed to explore self-reported use and non-use of six different ADAS among Swedish drivers using a 5-point Likert scale. Descriptive statistics including frequencies and a calculated summative level of agreement % is presented together with 95% confidence levels. Included in the analysis is those respondents reporting using ACC (n=1002), and/or LKA (n=461). Presented are limitations as experienced, frequency of use/non-use, and perceived driving experience. Results show that ACC is being activated (always/often) to a greater extent (84%) than LKA (57%), and for LKA it varies by frequency of driving. The majority of the participants had experienced more than one limitation (ACC:72%, LKA:68%), on a regular basis, which results in deactivation of the system. Only about 20 % (ACC:20%, LKA 18%) had never experienced that they could not use the ADAS. Those who do not experience any limitations, never experience the need to deactivate the ADAS to a greater extent- ACC: (38% vs 22%) and LKA (48% vs. 23%). Statistical significant tests relived a significant difference between LKA and ACC, in which LKA was affected to a greater extent for bad weather (48%), glare (48%), position in lane (27%), complex traffic (27%) while ACC was affected to a greater extent by dirty sensors (45%), complex traffic (43%), weather (31%). ACC also contribute (significantly) to a higher degree to a positive driving experience than LKA, likewise are more trusted and easier to use. This study highlights some of the reasons why ADAS are regularly turned off, diminishing their safety potential. Technological developments, together with standardization and infrastructure adaptation, may be required for ADAS to fully realize their safety potential.

INTRODUCTION

Today, vehicles often include systems that can help the driver steer, break, and keep distance to the vehicle ahead as well as warn when there is a crash risk. The introduction of advanced driver assistance systems, ADAS, (see table 1) is believed to have great potential for decreasing the number of fatalities in traffic [1], currently the 8th most common cause of death in the world with 1.35 million lives lost every year [2]. Research shows that vehicle crash safety has increased steadily since the 1980s [3], but the number of crashes also need to go down. Growing evidence from simulation studies, field operational tests and crash data analysis demonstrates that ADAS, individually and together, increase the safety of the vehicle and decrease the risk of crashes (e.g.,[4], [5]).

ADAS such as adaptive cruise control (ACC) and lane keep assist (LKA) are systems which, when active continuously help the driver maintain distance to vehicle ahead and/or in their lane, see Table 1. These systems are often referred to as 'comfort' systems. Yet, LKA could potentially have safety benefits as they could reduce the risk of running off road, drifting into oncoming vehicles and side swipes. ACC could also potentially contribute to a higher could reduce the potential for rear-end crashes. Indeed, it has been shown that forward collision warning with break support (CWB) combined with ACC, reduced rear-end crashes with frontal impacts with 38% [6]. Studies have also shown that LKA-equipped vehicles were 9% less likely (HR=0.91) to run off the road [7]. LKA did not have a significant effect on risk of same-direction sideswipes or head-on crashes [7].

However, these lateral ADAS are not without (technical) limitations [8], potentially resulting in less usage. Known limitations typically communicated to drivers includes lane division unclear, lane markings damage, sensors obstructed/damages, very hot/cold temperature [8]. However, there are large difference between different vehicle manufacturers. Other challenges impacting the system's ability to function such as adverse weather, bright light is rarely communicated [8]. Other limitations could be narrow, winding, and sloping roads, or construction zones. In addition, there are the system constrains for which the ADAS are designed to operate within (e.g., vehicle speed, road type).

To be safely used drivers need to be aware of its limitations. Trust and correct understanding of system functionality are considered key variables for appropriate system use [9]. It is encouraged that limitations "should be clearly defined and effectively communicated to the driver, and that drivers should be unable to engage the systems outside of the ODD [Operational Design Domain]" [10].

The majority of people participating in surveys express a positive attitude toward ADAS [11, 12]. However, studies have shown that the frequency of ADAS usage vary ([13-17], and the knowledge of their presence [16] or technical limitations vary [18, 19]. As drivers learn to use ADAS, they become more aware of the limitations with time, with unwanted system actions such as harsh responses to cut-ins, limits in maximum brake force, and limits in lead vehicle detection [20]. There is also a potential connection between low use of assistance systems, though available, and a belief that systems will not provide much of a benefit [21]. Also, research indicate that when learning about the ADAS focus on its limitations results in negative bias towards ADAS [22], indeed it has been shown that the quantity and quality of device-specific feature systematically affected drivers perception [23].

There are thus several known (technical) limitations that could potentially affect the perception and use of the ADAS. This paper report on a survey exploring ADAS usage and the limitations as experienced for ACC and LKA by Swedish drivers, in winter, known conditions to impact the ability to use the systems.

Table 1 Schematic overview of ADAS system from an accident prevention perspective derived from a driver's point of view. Developed from [24, 25].

Traffic situation	***Inform*** Static/temporal information	***Warn*** Temporal information via sound, graphic, or haptics	***Act*** Brake, limit engine power, and/or steer	
Reverse and park	Camera feed Parking sensors	Object detection	Rear-AEB	Parking assistance
Distance and speed	Set speed Road speed	Speed warning	Intelligent speed assistance	Cruise Control **Adaptive Cruise Control (ACC)**
Crash avoidance and mitigation		Collision warning Distance warning	AEB car/pedestrian /cyclist Emergency steering	**Lane Keep Assistance (LKA)** Assistance driving*
Safe in lane		Lane Departure Warning Blind spot detection		
Driving safe		Driver Monitoring Systems	Alcohol lock	

*Lane centring with Adaptive Cruise Control, e.g., piloting functions

METHOD

Research aims and objectives

The aim of the paper is to provide an overview of limitations as experienced by Swedish drivers and explore the possible outcome in terms of none/usage and perceived driving experience. More specifically the objective is to: (1) present descriptive statistics on limitations as experienced, frequency of use, driving experience and perceived benefits, (2) identify potential differences between the experienced limitations between LKA and ACC. The goal is to determine if the limitations as experienced influence the usage of ADAS.

Digital survey design

The digital survey was engineered using Netigate software. Survey design was based on previous studies examining the usage of ADAS (e.g., [26]). A total of 6 ADAS was included: Adaptive Cruise Control (ACC), Lane Keeping Assistance (LKA), Lane Departure Warning (LDW), Blind Spot Detection (BLIS), Forward

Collision Warning with or without Automatic Emergency Break for vehicle (AEB car) or pedestrian/cyclist detection (FCW/AEB VRU). After a set of demographics questions, respondents were asked about system availability in their vehicle(s). After system availability, each ADAS was presented separately with corresponding questions in which the driver were asked to respond to a set of statement via a 5-point Likert scale. The respondents were asked questions only about the systems they expressed they had in their vehicle and were reporting using. The survey was expected to take up to 15 minutes to complete.

Distribution

The survey was digitally distributed during March 2021 via a social media advertisement (Facebook) by Folksam Insurance Company: "Help us in our research on driver support system". The Facebook campaign had a reach of 144 300 and about 3985 unique hits. The demographics of the distribution was Sweden and people above 18, with no further specification regarding interests or group memberships.

The starting page of the questionnaire explained and asked those only within the target group to continue: Swedish drivers with a vehicle no older than model year 2009, with at least one of the following ADAS; Adaptive Cruise Control (ACC), Lane Keeping Assistance (LKA), Lane Departure Warning (LDW), Blind Spot Detection (BLIS), Forward Collision Warning with or without Automatic Emergency Break for vehicle (AEB car) or pedestrian/cyclist detection (FCW/AEB VRU). If the respondents chose that they did not have experience of any of the system, the survey ended.

Respondents

A total of 2521 participants started the survey. If the respondents did not have any of the requested systems and/or if the respondent did not answer all questions in the survey, then they were excluded from the final dataset (Table 2). A total of 1153 respondents reported having the ADAS on their current car: ACC (n=1113) and LKA (n=636). In this paper only respondents who explicitly stated that they use the ADAS are included LKA (n=461) and ACC (n=1002)). A total of 37 (4%) of the ACC respondents reported only having experience of ACC. It should be noted that the respondents of the questionnaire do not represent the total population of drivers Sweden (Table 3).

Table 2 Overview of the respondents' experienced ADAS. Includes answer from question: "Do you have experience of the following ADAS".

ADAS	*Respondents who have the system*	*Respondents who have the system and use it*	*Respondents who have the system, but do not use it*	*Respondents who do not have the system*	*Respondents who do not know if they have it*	*Included in analysis*
ACC	1113 (61%)	1002 (55%)	111 (6%)	683 (38%)	26 (2%)	1002
LDW	997 (55%)	754 (41%)	243 (13%)	795 (44%)	30 (2%)	
LKA	636 (35%)	461 (25%)	175 (9%)	1117(61%)	69 (4%)	461
BLIS	718 (39%)	680 (37%)	38 (2%)	1051 (58%)	53 (3%)	
AEB car	1214 (67%)	1163 (64%)	51 (3%)	569 (31%)	39 (2%)	
AEB VRU	868 (48%)	841 (46%)	27 (2%)	763 (42%)	191 (11%)	
Total	1822	1822				1039

Table 3 Representativeness of population. Comparison of distribution between percent of respondents (Re), number of persons holding a driving license (Dr) and number of car owner (Ow) in Sweden. Presented statistics is based on Swedish official population data provided by Statistics Sweden (SCB), 2022.

Gender/Age	*18-29y*			*30-39y*			*40-49y*			*50-59y*			*60y or older*		
	Re	Dr	Ow	Re	Dr	Ow	Re	Dr	Ow	Re	Dr	Ow	Re	Dr	Ow
Female	11	15	7	17	16	15	31	16	19	20	17	24	21	37	36
Male	7	15	8	15	17	16	22	16	19	23	18	22	33	34	35
Total	8	15	7	15	16	16	23	16	19	23	17	23	31	35	35

Analysis
The dataset includes responses to the experience and usage of ACC and LKA. Reported are respondent's demographics, frequency of use, limitations as experienced, perceived benefits, and positive driving experience. Descriptive statistics (frequency count and proportion) were calculated per survey item. A summative level of agreement response was calculated by adding 4-5 (coded as 1) on the Likert scale. Statistical analyses include the proportions and difference of proportions with 95% confidence limits, CL. The CL for a proportion is calculated with assumption of simple normal approximation binomial intervals. The CL for a difference is calculated with the same assumption. The Z-statistics is only calculated if n1p1(1-p1) >= 9 och n2p2(1-p2) >= 9. No correction for finite populations has been done. Statistical tests include statistically significant differences between ACC and LKA. Excel Power Pivot (v. 2108) and SAS Enterprise Guide (v. 8.3.0.103) were used for statistical analysis.

RESULTS

Respondent demographics

Of the 1822 respondents who completed the questionnaire, a total of 1039 are included of which 1002 respondents had ACC (96%) and 461 respondents had LKA (44%). The demographics of the respondents are presented in Appendix, Table A1. The majority of the respondents were 50 years or older (ACC: 53%; 55%), and male (ACC: 85%, LKA: 87%). The majority of the respondents consider themselves less prone to take risks with a mean between 3,7-3,5 on a 10 point Likert scale; the majority indicated 3 or less on the scale (ACC: 54%, LKA: 55%). On the technology readiness scale the majority identified themselves as early adopter (ACC: 56%, LKA: 62%)) or early majority (ACC:33%, LKA 27%). Most of the respondents were positive towards using drivers support systems in general (ACC: 70%, LKA 75%). The majority lived in urban areas (55%), while the rest lived either in a large city (Stockholm/ Göteborg/ Malmö) (ACC: 24%, LKA:26%) or rural area (ACC: 20%, LKA: 19%). The majority of respondents lived in the south of Sweden which corresponds to the population concentration in Sweden. Most respondents had 5 ADAS or more (ACC: 49%, LKA,83%). A total of 37 (4%) of the ACC respondents reported only having experience of ACC.

Limitations as experienced by respondents

The majority of the respondents had experienced limitations and situations in which they could not activate the ADAS (ACC:72%, LKA:68%), table 4. Only about 20% (ACC:20%, LKA 18%) had never experienced any situation for which they could not use the ADAS. For ACC dirty sensors (45%) and complex traffic situation (43%) is commonly experienced. For LKA weather (48%) and glare (45%) is commonly experienced. Only about 25% had never experienced that they needed to deactivate the system due to negative driving experience (ACC: 25%, LKA:26%), table 6. Only a limited amount of people had often or always experienced that they had to turn off the system due to a negative experience (ACC: 3%, LKA: 6%), table 6. Statistical significant tests relived a significant difference between LKA and ACC, in which LKA was affected to a greater extent for bad weather, darkness, and glare, while ACC was affected to a greater extent by complex traffic situation, dirty sensors (Table, 4). A majority of the respondents had experience more than one limitation, see table 5. Those who did not experience any limitations (ACC: n=177, LKA n=52), never experience the need to deactivate the ADAS to a greater extent compared to those that experienced at least one limitation- ACC: (38% vs 22%) and LKA (48% vs. 23%). Subsequent statistical analysis shows a statistical significance between ACC and LKA, table 8 and 9. When excluding those who only had experience one of the systems, there are no significant difference in frequency (0-5) experienced limitations between ACC and LKA (cf., table 5).

Table 4 Specification of experienced situations the respondents had to turn off the system even though they wanted to use it. The respondents could answer one or more situations.

Reason to deactivate ADAS	*ACC (n=1002)*	*LKA (n=461)*	*Difference in proportion [%]*	*95% CI for difference*	*Significance level (p-value)*
*Total, turning off**	726 (72%)	312 (68%)	4.78	-0.31 – 9.86	0.0616
Weather	315 (31%)	221 (48%)	-16.20	-21.60 – -10.81	<.0001***
Darkness	68 (7%)	95 (21%)	-13.82	-17.83 – -9.81	<.0001***
Glare	62 (6%)	208(45%)	-38.93	-43.71 – -34.15	<.0001***
Positioning in lane	n/a	124 (27%)	n/a		

Complex traffic	432 (43%)	124 (27%)	16.22	11.14 – 21.29	<.0001***
Dirty sensors	451 (45%)	60 (13%)	31.99	27.64 – 36.34	<.0001***
No situations	203 (20%)	82 (18%)	2.47	-1.82 – 6.76	0.2674
Other	86 (9%)	33 (7%)	1.42	-1.50 – -1.50	0.3545

**due to negative driving experience / no time of turning off*

Table 5 overview of the number of limitations respondents indicated from a pre-set list (available alternatives: bad weather, darkness, glare, complex traffic situation, dirty sensors, no experienced situations, position in lane, other), respondents who indicated "no situation" is denoted as "0". Respondents could indicate one or more alternatives.

No. ADAS Limitations	*ACC (n=1002)*	*LKA (n=461)*	*Difference in proportion [%]*	*95% CI for difference*	*Significance level (p-value)*
0	177(18%)	34(7%)	10.29	6.93 – 13.65	<.0001***
1	421(42%)	219(48%)	-5.49	-10.98 – 0.00	0.0493*
2	272(27%)	125(27%)	0.03	-4.87 – 4.93	0.9902
3	92(9%)	62(13%)	-4.27	-7.86 – -0.68	0.0135*
4	27(3%)	19(4%)	-1.43	-3.50 – 0.65	0.1463
5	13(1%)	2(0%)	0.86	-0.06 – 1.79	1.0000
6	0(0%)	0(0%)	0.00	-0.00 – 0.00	1.0000

Table 6. Do you deactivate the system as it negatively contribute to your driving experience divided according to number of limitations as experienced.

Deactivate of ADAS	ACC 0 limitations experienced (n=177)	ACC 1-5 limitations experienced (n=825)	LKA 0 limitations experienced (n=52)	LKA 1-5 limitations experienced (n=409)
Always	2(1%)	11(1%)	0(0%)	7(23%)
Often	3(2%)	40 (5%)	2(4%)	34(8%)
Sometime	43(24%)	280 (34%)	10 (19%)	153 (37%)
Rarely	57(32%)	290 (35%)	10 (19%)	96(24%)
Never	68 (38%)	184 (22%)	25(48%)	95 (23%)

Table 7. Respondents experience the need to deactivate the system due to negative experience.

Deactivation due to negative driving experience	*ACC (n=1002)*	*LKA (n=461)*	*Difference in proportion [%]*	*95% CI for difference*	*Significance level (p-value)*
Never	252 (25%)	120 (26%)	-23.44	-28.74 – -18.15	<.0001***
Rarely	347 (34%)	106 (23%)	13.37	8.62 – 18.13	<.0001***
Sometime	323 (32%)	163 (35%)	11.85	7.17 – 16.53	<.0001***
Often	43(4%)	36 (8%)	0.60	-1.53 – 2.73	0.5885
Always	13 (1%)	7 (1%)	0.43	-0.67 – 1.53	1.0000
Cannot answer	24 (2%)	26 (6%)			

Table 8. Do you deactivate the ACC as it negatively contribute to your driving experience divided according to number of experienced limitations.

Deactivate of ADAS	ACC 0 experienced limitations (n=177)	ACC 1-5 experienced limitations (n=825)	Difference in proportion [%]	95% CI for difference	Significance level (p-value)
Always	2(1%)	11(1%)	-0.20	-1.95 – 1.54	1.0000
Often	3(2%)	40 (5%)	-3.15	-5.55 – -0.75	1.0000
Sometime	43(24%)	280 (34%)	-9.95	-16.74 – -2.55	0.0127*
Rarely	57(32%)	290 (35%)	-2.95	-10.56 – 4.67	0.4545
Never	68 (38%)	184 (22%)	16.12	8.41 – 23.82	<.0001***

Table 9. Do you deactivate the LKA as it negatively contribute to your driving experience divided according to number of experienced limitations.

Deactivate of ADAS	LKA 0 experienced limitations (n=52)	LKA 1-5 experienced limitations (n=409)	Difference in proportion [%]	95% CI for difference	Significance level (p-value)
Always	0(0%)	7(23%)	-1.71	-2.97 – -0.45	1.0000
Often	2(4%)	34(8%)	-4.47	-10.34 – 1.41	1.0000

Sometime	10 (19%)	153 (37%)	-18.18	-29.87 – -6.48	1.0000
Rarely	10 (19%)	96(24%)	-4.24	-15.71 – 7.23	1.0000
Never	25(48%)	95 (23%)	24.85	10.67 –39.03	0.0001**

Activation of ADAS

The respondents were also asked to indicate how often they used a particular ADAS when driving, Table 10. The result indicates that the participants use the system often (ACC: 37%, LKA: 25%) or always (ACC: 47%, LKA:32%) with ACC being used to a greater extent than LKA (p <.0001). The use of ADAS also varies by driving frequency for LKA (% agreement of activation of ADAS increase by the frequency of drive) but are more stable across the respondents for ACC (ranging between 83-90%), figure 1, table 12-13.

The respondents were asked in which specific traffic conditions they felt comfortable using the ADAS, Table 11. Most respondents were comfortable to use the system on highways (ACC 97%, LKA: 88%). Fewer respondents feel comfortable using ADAS near roadworks (ACC: 17%, LKA:8%) and on curvy roads (ACC: 32%, LKA 26%). There is also lower usage in high intensity traffic (ACC: 41%, LKA: 32%). ACC and LKA follow a similar pattern, but LKA consistently receives lower scores in each traffic condition. The difference is statistically significant for the different attributes (p<0.05).

Table 10. Activation of ADAS. Includes answer from question: How often do you use the ADAS in your current used vehicle?

Frequency of activation	*ACC (n=1002)*	*LKA (n=461)*	*Difference in proportion [%]*	*95% CI for difference*	*Significance level (p-value)*
% agreeness (always/often)	84%	57%			
Always	474 (47%)	148 (32%)	15.20	9.94 – 20.47	<.0001***
Often	371 (37%)	113 (25%)	12.51	7.58 –17.45	<.0001***
Sometime	128 (13%)	134 (29%)	-16.29	-20.92 – -11.66	<.0001***
Rarely	24 (2%)	43 (9%)	-6.93	-9.75 – -4.11	<.0001***
No knowledge	5 (1%)	23 (5%)	-4.49	-6.53 – -2.46	1.0000

Table 11 Respondents comfortable using ADAS in different traffic environments. Includes answer to question: on what roads/traffic conditions are you comfortable to use the system?

Type of road	*ACC (n=1002)*	*LKA (n=461)*	*Difference in proportion [%]*	*95% CI for difference*	*Significance level (p-value)*
Country roads	913 (91%)	375 (81%)	9.77	5.80 – 13.74	<.0001***
City streets	368 (37%)	113 (25%)	12.21	7.28 – 17.15	<.0001***
Highway	968 (97%)	405 (88%)	8.75	5.57 – 11.94	<.0001***
Roads with separated lanes (2+1 lanes)	833 (83%)	321 (70%)	13.50	8.71 – 18.30	<.0001***
curvy roads	316 (32%)	118 (26%)	5.94	1.03 – 10.85	0.0208*
Roads with traffic lights and/or round about	229 (23%)	65 (14%)	8.75	4.65 – 12.86	0.0001**
Low intensity traffic	567 (57%)	203 (44%)	12.55	7.08 – 18.03	<.0001***
High intensity traffic	410 (41%)	149 (32%)	8.60	3.35 – 13.84	0.0017*
Roadwork	167 (17%)	35 (8%)	9.07	5.73 – 12.42	<.0001***
Slow traffic	552 (55%)	159 (34%)	20.60	15.28 – 25.92	<.0001***

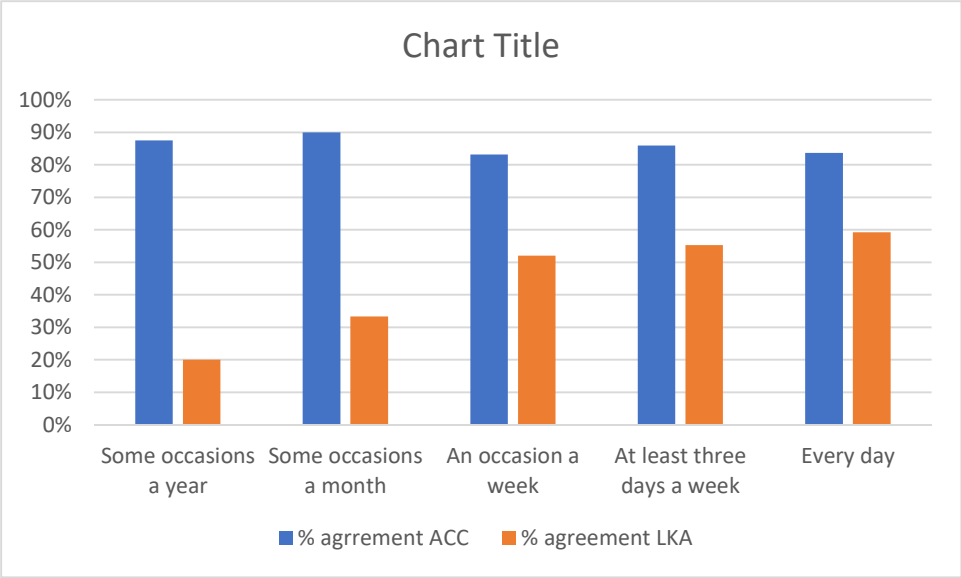

Figure 1 Overview of frequency of drive and activation of ACC and LKA (% agreement: (often/always) activated). See table 12, 13.

Table 12 Activation of ACC vs driving frequencies

Frequency of activation	*Some occasions a year*	95% CI	*Some occasions a month*	95% CI	*An occasion a week*	95% CI	*At least three days a week*	95% CI	*Every day*	95% CI	*Total*	95% CI
Always	2 (0%)	-0.08 – 0.48	8 (1%)	0.25 – 1.35	56 (6%)	4.17 – 7.01	120 (12%)	9.97 – 13.99	288 (29%)	25.94 – 31.54	474 (47%)	44.21 – 50.40
Often	5 (1%)	0.06 – 0.94	10 (1%)	0.25 – 1.35	43 (4%)	3.04 – 5.55	106 (11%)	8.67 – 12.48	207 (21%)	18.15 – 23.17	371 (37%)	34.04 – 40.02
Sometime	0 (0%)		2 (0%)	-0.08 – 0.48	18 (2%)	0.97 – 2.62	27 (3%)	1.69 – 3.70	81 (8%)	6.40 – 9.77	128 (13%)	10.71 – 14.84
Rarely	1 (0%)	-0.10 – 0.30	0 (0%)		2 (0%)		8 (1%)	0.25 – 1.35	13 (1%)	0.60 – 2.00	24 (2%)	1.45 – 3.34
No knowledge	0 (0%)		0 (0%)		0 (0%)		2 (0%)		3 (0%)		5 (1%)	0.06 – 0.94
No answer	0 (0%)		0 (0%)		0 (0%)		0 (0%)		0 (0%)		0 (0%)	
Total	8 (1%)	0.25 – 1.35	20 (2%)	1.13 – 2.86	119 (12%)	9.87 – 13.88	263 (26%)	23.52 – 28.97	592 (59%)	56.04 – 62.13	1002 (100%)	

Table 13. Activation of LKA vs driving frequencies

Frequency of activation	*Some occasions a year*	95% CI	*Some occasions a month*	95% CI	*An occasion a week*	95% CI	*At least three days a week*	95% CI	*Every day*	95% CI	*Total*	95% CI
Always	1 (0%)	-0.21 – 0.64	0 (0%)		15 (3%)	1.63 – 4.87	47 (10%)	7.43 – 12.90	85 (18%)	14.90 – 21.98	148 (32%)	27.84 – 36.37
Often	0 (0%)		2 (0%)	-0.17 – 1.03	10 (2%)	0.84 – 3.50	26 (6%)	5.36 – 10.26	75 (16%)	12.90 – 19.64	113 (25%)	20.59 – 28.44
Sometime	3 (1%)	-0.08 – 1.38	3 (1%)	-0.08 – 1.38	17 (4%)	1.97 – 5.41	35 (8%)	5.17 – 10.01	76 (16%)	13.10 – 19.87	134 (29%)	24.92 – 33.21
Rarely	1 (0%)	-0.21 – 0.64	0 (0%)		3 (1%)	-0.08 – 1.38	15 (3%)	1.63 – 4.87	24 (5%)	3.18 – 7.23	43 (9%)	6.67 – 11.98
No knowledge	0 (0%)		1 (0%)	-0.21 – 0.64	3 (1%)	-0.08 – 1.38	9 (2%)	0.69 – 3.22	10 (2%)	0.84 – 3.50	23 (5%)	3.00 – 6.98
No answer	0 (0%)		0 (0%)		0 (0%)		0 (0%)		0 (0%)		0 (0%)	
Total	5 (1%)	0.14 – 2.03	6 (1%)	0.27 – 2.34	48 (10%)	7.82 – 13.20	132 (29%)	24.51 – 32.76	270 (59%)	54.07 – 63.07	461 (100%)	

Perceived driving experience

The respondents were asked if the specific ADAS contributed to a positive driving experience. ACC contributed to a larger extent to a positive driving experience as compared to LKA (ACC 86% vs. LKA 64%, p<0.0001). Considering how the system contribute to the driving experience LKA is considered to a lager extent as a safety system by the respondents compared to ACC (LKA 72% and ACC 25%). Subsequent statistical analysis show statistically significant difference (p<0.001). LKA is also considered to a greater extent to increase mental ease (p< 0.001). ACC is mainly reportedly used to decrease fuel consumption (45%). Only a minority of the respondents uses the ADAS to enable the performance of other activities that are not related to driving (ACC: 6%, LKA: 10%).

There is a significant difference in trusting the ADAS to maintain distance to vehicle in front (ACC, 88%) or maintain position in lane (LKA, 56%) (p<0.001).

Table 14. ADAS Contributes to a positive driving experience. Includes respondents answer to the question: the ADAS contribute to a positive driving experience?

Positive driver experience	*ACC (n=1002)*	*LKA (n=461)*	*Difference in proportion [%]*	*95% CI for difference*	*Significance level (p-value)*
% agreement (4/5)	853 (85%)	294 (64%)	21.36	16.45 – 26.67	<.0001***
Strongly agree (5)	535(54%)	152 (33%)	20.42	15.13 – 25.71	<.0001***
Agree to large extent (4)	318 (32%)	142(31%)	0.93	-4.17 – 6.04	0.7208
Somewhat agree (3)	122(12%)	110 (24%)	-11.69	-16.07 – -7.30	<.0001***
Disagree (2)	15 (2%)	20 (4%)	-2.84	-4.85 – -0.84	0.0010*
Strongly disagree (1)	4 (0.4%)	11 (2%)	-1.99	-3.43 – -0.54	1.0000
Cannot answer	8 (1%)	26 (6%)	-4.84	-7.02 – -2.66	1.0000

Table 15 Respondents answer to the question: How does the ADAS use contributes to the driving experience?

Type of positive experience	*ACC (n=1002)*	*LKA (n=461)*	*Difference in proportion*	*95% CI for difference*	*Significance level (p-value)*

			[%]		
Increased safety	252 (25%)	333 (72%)	-47.08	-51.98 – -42.19	<.0001***
Increased physical comfort	315 (31%)	215 (47%)	-15.20	-20.59 – -9.82	<.0001***
Increased mental ease	68 (7%)	221 (48%)	-41.15	-45.97 – -36.33	<.0001***
Decreased fuel consumption	451 (45%)	45 (10%)	35.25	31.15 – 39.35	<.0001***
Opportunities to do other things	62 (6%)	44 (10%)	-3.36	-6.43 – -0.29	0.0214*
Becoming a better driver	432 (43%)	125 (27%)	16.00	10.91 – 21.09	<.0001***
More enjoyable driving	203 (20%)	42 (9%)	11.15	7.53 – 14.77	<.0001***
Other	86 (9%)	36 (8%)	0.77	-2.23 – 3.77	0.6190

Table 16 Overall experience with ACC and LKA

Type of experience	*ACC (n=1002)*	*LKA (n=461)*	*Difference in proportion [%]*	*95% CI for difference*	*Significance level (p-value)*
Trust: Keeps speed and distance to vehicle in front / keep the car in the middle of lane	884 (88%)	256 (56%)	32.69	27.74 – 37.65	<.0001***
Accelerates and brakes smoothly	798 (80%)	n/a			
Been helpful in dangerous situations	448 (45%)	106 (23%)	21.72	16.79 – 26.64	<.0001***
Increases risk to be in dangerous situations	53 (5%)	23 (5%)	0.30	-2.12 – 2.72	0.8100
Have good understanding of function of system	956 (95%)	378 (82%)	13.41	9.67 – 17.15	<.0001***
Is easy to use	952 (95%)	375 (81%)	13.67	9.86 – 17.47	<.0001***
Good collaboration in driving the car	780 (78%)	n/a			
Fights against the system	n/a	32 (7%)			

DISCUSSION

Studies have shown that many ADAS, both individually and in combination, can increase the safety of a vehicle and reduce the risk of personal injury, e.g., [4, 5, 27, 28]. However, there are known limitations to ADAS that can impact their effectiveness [8]. A combination of technical limitations in sensor technology and variations in driving conditions reduce their ability to be used.

This study confirms previous research that ADAS are being used in daily driving, with Adaptive Cruise Control (ACC) being used (significantly) more frequently than Lane Keeping Assist (LKA). However, the study highlights that most respondents experienced limitations and the respondents regularly turn off the systems, limiting their potential effectiveness. Research has indicated that limitations can affect the use and perceived value of ADAS [13]. Even the naming of the systems influences the driver's perception of its capabilities [29].

Previous studies have listed possible technical limitations that could limit the use of ADAS [8]. This study revealed a significant difference between LKA and ACC in terms of situations for which the driver experienced that they could not use the system (i.e., limitations as experienced): LKA was more affected by bad weather (48%), glare (48%), position in lane (27%), and complex traffic (27%), while ACC was more affected by dirty sensors (45%), complex traffic (43%), and weather (31%).

Previous studies have shown that bad weather conditions had no substantial impact on driving behaviour (e.g., frequency of activation) [30]. This study shows that 31% of the ACC respondents and almost 50% of the LKA respondents were limited by bad weather. However, as the author note in [30], the absence of results may be due to the absence of extreme weather during the test period. ADAS performance in adverse weather and different light conditions will come into focus in the coming years, as EuroNCAP have released their Vision 2030 with an increased effort of testing systems in a multitude of conditions [31].

As the study of [30], and this study, complex traffic is experienced as a limited factor more frequently than bad weather, but, in this study it was only true for ACC (not LKA). Previous research has identify that traffic conditions to be the most critical part of the driving context [30]. The study shows that respondents, as previously indicated, are comfortable using ACC and LKA on highway (ACC: 97%, 88%) and country roads (ACC: 91%, LKA: 81%). Less on curvy roads and by road works. This study thus show that many respondents are affected by the driving context (e.g., road type, traffic intensity) and that it limits the use of ADAS. Interestingly, as much as 27% of the respondents using LKA have turned of the system due to position in lane. 7% of the LKA respondents consider that they have to argue with the system. Previous research has identified that: "Situations where drivers reported feeling uncomfortable with the automation during their drive were

dominated by instances where lane centring struggled with common roadway features such as hills and intersections"[26]. This research confirms that the respondents feel less comfortable using the systems on curvy roads (ACC:32%, LKA: 26%); most participants feel comfortable using the systems on Personalisation, and a greater flexibility in the system may be required for decreasing the frequency of experience of this limitation.

Previous studies have shown a variety of frequency of use vary [13-17]. In this study the majority of the respondents uses the systems often or always (ACC:85%, LKA 64%). But we also see that a majority of the respondents had experienced the need to turn off the ADAS system due to a negative driving experience (only 25% for ACC and 26% for LKA had never experienced the need to turn it off). The frequency of turning off the system also significantly varies depending on the specific ADAS technology being used. Previous research has indiated a "strong relationship between system activation and the capability to prevent lane drifts and the timing of steering input" [32]. In this study we see that ACC positively contributes to the driving experience (85%) and is experienced to accelerate and break smoothly (80%), and is experienced to have a good collaboration (78%).

The benefits of ADAS to the driving experience have been previously identified as a factor influencing its usage [21]. This study highlights that of the choses given (table 13): ACC are being used to decrease fuel consumption (ACC: 45%) and to become a better driver (43%), while LKA is being used to increase safety (71%), physical comport (47%), mental ease (48%).

For these systems to be safely used, research has highlighted the need that drivers understand their limitations [18-19]. Previous research has demonstrated that there is a lack of awareness or understanding of key limitations in ADAS [12]. However, the respondents in this survey judge themselves having good understanding of the function of system (ACC: 95%, LKA 82%). The result from the presented survey indicates that even though respondents experience limitations in their use of the systems, they believe that the systems positively contribute to the driving experience; at least for ACC (ACC:85%, LKA 64%). Previous research has identified pleasantness of use and perceived benefits as most important factors determine the use of ADAS [23].

The results from this paper show that the trust towards the ACC (88%) is higher than LKA (56%) with a significant difference. Previous research has shown that "automation failures do not negatively affect trust and acceptance if they are known beforehand"[9]. This research indicates no significant difference in experienced limitations (comparing 0 limitations vs. 1-5 limitations) for those who turned off the system at least once due to negative driving experience. This study shows that 95% of those using ACC consider that they have a good understanding of system functionality, significant lower for LKA (82%). Trust and correct understanding of system functionality are considered key variables for appropriate system use [9]. Due to sensor limitations, not every situation can be handled by the system and, therefore, driver intervention is required.

Throughout this study it is shown that ACC significantly differ from LKA and, ACC consistently receives better scores. Previous research has identified a difference between LKA and ACC. For instance, the study by [26] indicated that "drivers reported significantly higher trust in adaptive cruise control than in lane centering".

There is thus more work needed, especially for LKA. Experienced limitations influence the frequency of use. Future studies include identifying the effect of respondent demographics, attitude towards the system and the frequency of experience of limitations. Future studies should also include a wider population to better represent the total of Swedish drivers.

Limitations

The study was distributed via social media and based on self-reported experiences, and though care has been made to describe systems clearly, there may still be some confusion. Also, one should take care with the results as the respondents cannot be considered to be representative of all Swedish drivers.

CONCLUSION

Studies have shown that many ADAS, on their own and together, increase the safety of the vehicle and lower the risk of personal injury. However, for the systems to fulfil their safety potential they need to be used. This study highlights that the majority of the respondents experience limitations, and they regularly experience the need to turn off the systems. The study reveals that the limitations as experienced significantly varies depending on the specific ADAS technology. For ADAS to fully realize their safety potential, technological advancements, standardization efforts, and infrastructure adaptations may be necessary. This study is based on a self-reported survey and may not represent the view of all drivers in Sweden.

REFERENCES

1. Lubbe, N., et al. *Predicted road traffic fatalities in Germany: The potential and limitations of vehicle safety technologies from passive safety to highly automated driving*. in *Proceedings of IRCOBI conference*. 2018. Athens, Greece.
2. WHO, *Global Status Report on Road Safety 2018*. 2018, World Health Organization: Geneva, Switzerland.
3. Kullgren, A., H. Stigson, and A. Axelsson, *Developments in car crash safety since the 1980s* in *IRCOBI*. 2020. p. 86-99.
4. Cicchino, J.B., *Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates.* Accident Analysis & Prevention, 2017. **99**: p. 142-152.
5. Sternlund, S., et al., *The effectiveness of lane departure warning systems—A reduction in real-world passenger car injury crashes.* Traffic Injury Prevention, 2017. **18**(2): p. 225-229.
6. Isaksson-Hellman, I. and M. Lindman, *Evaluation of Rear-End Collision Avoidance Technologies based on Real World Crash Data*, in *Proc. 3rd International Symposium on Future Active Safety Technology towards zero traffic accidents*. 2015: Gothenburg. p. 471-476.
7. Spicer, R., Vahabaghaie, A., Murakhovsky, D., Bahouth, G., Drayer, B., Lawrence, S, *Effectiveness of Advanced Driver Assistance Systems in Preventing System-Relevant Crashes.* SAE Int. J. Adv. & Curr. Prac. in Mobility 2021. **3**(4): p. 1697-1701.
8. Capallera, M., Meteier, Q., de Salis, E., Angelini, L., Carrino, S., Kahale, O A., Mugellini. *Owner Manuals Review and Taxonomy of ADAS Limitations in Partially Automated Vehicles*. in *AutomotiveUI '19: Proceedings of the 11th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. 2019. Netherlands.
9. Beggiato, M. and J.F. Krems, *The evolution of mental model, trust and acceptance of adaptive cruise control in relation to initial information.* Transportation Research Part F: Traffic Psychology and Behaviour, 2013. **18**: p. 47-57.
10. Mueller, A.S., I.J. Reagan, and J.B. Cicchino, *Addressing Driver Disengagement and Proper System Use: Human Factors Recommendations for Level 2 Driving Automation Design.* Journal of Cognitive Engineering and Decision Making, 2021. **15**(1): p. 3-27.
11. Caber, N., P. Langdon, and P.J. Clarkson. *Designing Adaptation in Cars: An Exploratory Survey on Drivers' Usage of ADAS and Car Adaptations*. in *Advances in Human Factors of Transportation*. 2020. Cham: Springer International Publishing.
12. McDonald, A., C. Carney, and D.V. McGehee, *Vehicle Owners' Experiences with and Reactions to Advanced Driver Assistance Systems (technical report)*, in *AAA Foundation for Traffic Safety*. 2018: Washington, D.C.
13. Lijarcio, I., et al., *Availability, Demand, Perceived Constraints and Disuse of ADAS Technologies in Spain: Findings From a National Study.* IEEE Access, 2019. **7**: p. 129862-129873.
14. Boelhouwer, A., et al., *How are car buyers and car sellers currently informed about ADAS? An investigation among drivers and car sellers in the Netherlands.* Transportation Research Interdisciplinary Perspectives, 2020. **4**: p. 100103.
15. Reagan, I.J., et al., *Disengagement from driving when using automation during a 4-week field trial.* Transportation Research Part F: Traffic Psychology and Behaviour, 2021. **82**: p. 400-411.
16. Harms, I.M., L. Bingen, and J. Steffens, *Addressing the awareness gap: A combined survey and vehicle registration analysis to assess car owners' usage of ADAS in fleets.* Transportation Research Part A: Policy and Practice, 2020. **134**: p. 65-77.
17. Wozniak, D., et al., *Analysis of advanced driver assistance systems in police vehicles: A survey study.* Transportation Research Part F: Traffic Psychology and Behaviour, 2021. **83**: p. 1-11.
18. DeGuzman, C.A. and B. Donmez, *Drivers Still Have Limited Knowledge About Adaptive Cruise Control Even When They Own the System.* Transportation Research Record, 2021: p. 03611981211011482.
19. Hungund, A.P. and A.K. Pradhan, *A survey on knowledge and perceptions of advanced driver assistance systems in Massachusetts drivers.* Traffic Injury Prevention, 2022: p. 1-3.
20. Larsson, A.F., *Driver usage and understanding of adaptive cruise control.* Appl Ergon, 2012. **43**(3): p. 501-6.
21. Larsson, A. and K. Emanuelsson, *Examining Factors for Low Use of Driver Assistance Systems*, in *In FAST-zero*. 2021.
22. DeGuzman, C.A. and B. Donmez, *Drivers don't need to learn all ADAS limitations: A comparison of limitation-focused and responsibility-focused training approaches.* Accident Analysis & Prevention, 2022. **178**: p. 106871.
23. Biassoni, F., D. Ruscio, and R. Ciceri, *Limitations and automation. The role of information about device-specific features in ADAS acceptability.* Safety Science, 2016. **85**: p. 179-186.

24. NHTSA, *Vehicle Shopper's Guide: Driver Assistance Technologies*. 2018.
25. AAA, *Advanced driver assistance technology names: AAA's recommendation for common naming of advaced safety systems*. 2019.
26. Reagan, I.J., J.B. Cicchino, and D.G. Kidd, *Driver acceptance of partial automation after a brief exposure.* Transportation Research Part F: Traffic Psychology and Behaviour, 2020. **68**: p. 1-14.
27. Sternlund, S., *The safety potential of lane departure warning systems—A descriptive real-world study of fatal lane departure passenger car crashes in Sweden.* Traffic Injury Prevention, 2017. **18**(sup1): p. S18-S23.
28. Cicchino, J., *Effects of automatic emerency braking systems on pedestrian crash risk*. 2022.
29. Teoh, E.R., *What's in a name? Drivers' perceptions of the use of five SAE Level 2 driving automation systems.* Journal of Safety Research, 2020. **72**: p. 145-151.
30. Orlovska, J., et al., *Effects of the driving context on the usage of Automated Driver Assistance Systems (ADAS) -Naturalistic Driving Study for ADAS evaluation.* Transportation Research Interdisciplinary Perspectives, 2020. **4**: p. 100093.
31. NCAP, E., *Euro NCAP vision for 2030 A safer future for mobility* 2022.
32. Reagan, I.J., J.B. Cicchino, and C.J. Montalbano, *Exploring relationships between observed activation rates and functional attributes of lane departure prevention.* Traffic Inj Prev, 2019. **20**(4): p. 424-430.

APPENDIX

Table A 1. Overview of respondents' demographics.

Demographics	**ACC (n=1002)**	**LKA (n=461)**
Year		
18-29	73 (7%)	23 (5%)
30-39	151 (15%)	59 (13%)
40-49	243(24%)	128 (28%)
50-59	243 (24%)	127 (28%)
>60	292 (29%)	124 (27%)
Gender		
Female	143 (14%)	59 (13%)
male	853 (85%)	399 (87%)
Other /do not want to specify	6(0.6%)	3 (0.6%)
Living environment		
City (Stockholm, Göteborg, Malmö)	243(24%)	119(26%)
Urban	555(55%)	253(55%)
rural area	204(20%)	89(19%)
Risk taking in traffic (1-10)	3,7 Mean	3,5 Mean
Technology readiness		
Innovator	65 (6%)	40 (8%)
Early adopter	559 (56%)	284(62%)
Early majority	332 (33%)	126 (27%)
Late majority	30 (3%)	7(2%)
Laggards	9(1%)	2 (1%)
Top 5 represented vehicle brands	Volvo (343/34%), Volkswagen (183/18%), Kia (69/7%), Skoda (54/5%), Toyota (46/5%)	Volvo (150/32%), Kia (57/12%), Volkswagen (48/11%), Tesla (40/8%), Hyundai (20/4%)
Attitude towards ADAS systems		
Very negative	6 (1%)	1 (0.2%)
Fairly negative	15 (2%)	3 (1%)
Neutral	40 (4%)	13 (3%)
Little positive	246 (25%)	96 (21%)
Very positive	695 (70%)	348 (75%)
Frequency of driving		
Daily	592 (59%)	270 (59%)
Minimum 3 days a week	263 (26%)	32 (29%)
At least once a week	119 (12%)	48 (10%)
At least once a month	20 (2%)	6 (1%)
At least once a year	8 (1%)	5 (1%)
Experience of vehicle		
month	(262/26%)	28 (6%)
1-6 months	(185/18%)	113 (25%)
7-12 months	(165/16%)	83 (18%)

13-24 months	(262/26%)	126 (27%)
>24months	(350/35%)	110 (24%)
Number of ADAS systems		
1	37 (4%)	0 (0%)
2	101 (10%)	6 (1%)
3	145 (15%)	19 (4%)
4	226 (23%)	48 (10%)
5	238 (24%)	133 (28%)
6	255 (25%)	255 (55%)

Table 17 ACC contributes to positive driving experience versus driving frequencies

Type of positive experience	*Some occasions a year*	*Some occasions a month*	*An occasion a week*	*At least three days a week*	*Every day*	*Total*
Increased security	0 (0%)	3 (0%)	27 (3%)	63 (6%)	159 (16%)	252 (25%)
Increased fysical comfort	3 (0%)	5 (1%)	35 (3%)	79 (8%)	193 (19%)	315 (31%)
Increased mental relaxation	0 (0%)	1 (0%)	10 (1%)	20 (2%)	37 (4%)	68 (7%)
Opportunities to do other things	0 (0%)	0 (0%)	9 (1%)	18 (2%)	35 (3%)	62 (6%)
Becoming a better driver	5 (1%)	10 (1%)	63 (6%)	105 (10%)	249 (25%)	432 (43%)
Decreased fuelconsumption	6 (1%)	9 (1%)	44 (4%)	99 (10%)	293 (29%)	451 (45%)
More enjoyable cardriving	0 (0%)	7 (1%)	24 (2%)	52 (5%)	120 (12%)	203 (20%)
Other	0 (0%)	0 (0%)	9 (1%)	30 (3%)	47 (5%)	86 (9%)

Table 18 LKA contributes to positive driving experience versus driving frequencies

Type of positive experience	*Some occasions a year*	*Some occasions a month*	*An occasion a week*	*At least three days a week*	*Every day*	*Total*
Increased security	3 (1%)	4 (1%)	40 (9%)	99 (21%)	187 (41%)	333 (72%)
Increased fysical comfort	1 (0%)	4 (1%)	25 (5%)	56 (12%)	129 (28%)	215 (47%)
Increased mental relaxation	1 (0%)	5 (1%)	28 (6%)	60 (13%)	127 (28%)	221 (48%)
Opportunities to do other things	0 (0%)	0 (0%)	5 (1%)	13 (3%)	26 (6%)	44 (10%)
Becoming a better driver	0 (0%)	2 (0%)	22 (5%)	29 (6%)	72 (16%)	125 (27%)
Decreased fuelconsumption	1 (0%)	0 (0%)	5 (1%)	8 (2%)	31 (7%)	45 (10%)
More enjoyable cardriving	1 (0%)	0 (0%)	9 (2%)	11 (2%)	21 (5%)	42 (9%)
Other	1 (0%)	1 (0%)	3 (1%)	10 (2%)	21 (5%)	36 (8%)

Table 19 Overall experiences with ACC versus driving frequencies

Type of experience	*Some occasions a*	*Some*	*An*	*At least three days*	*Every day*	*Total*

	year	*occasions a month*	*occasion a week*	*a week*		
Contributes to a positive driving experience	5 (1%)	17 (2%)	103 (10%)	231 (23%)	497 (50%)	853 (85%)
Keeps speed and distances to vehicle in front	7 (1%)	18 (2%)	105 (10%)	238 (24%)	516 (52%)	884 (88%)
Accelerates and brakes smoothly	7 (1%)	14 (1%)	102 (10%)	211 (21%)	464 (64%)	798 (80%)
Been helpful in dangerous situations	2 (0%)	8 (1%)	56 (6%)	117 (12%)	265 (26%)	448 (45%)
Increases risk to be in dangerous situations	0 (0%)	0 (0%)	10 (1%)	15 (2%)	28 (3%)	53 (5%)
Have good understanding of function of system	7 (1%)	19 (2%)	112 (11%)	246 (25%)	572 (57%)	956 (95%)
Is easy to use	7 (1%)	18 (2%)	108 (11%)	253 (25%)	566 (56%)	952 (95%)
Good coworking in driving the car	5 (1%)	13 (1%)	92 (9%)	216 (22%)	454 (45%)	780 (78%)
Feels to disconnected from driving the car	1 (0%)	0 (0%)	2 (0%)	4 (0%)	22 (2%)	29 (3%)

Table 20 Overall experiences with LKA versus driving frequencies

Type of experience	*Some occasions a year*	*Some occasions a month*	*An occasion a week*	*At least three days a week*	*Every day*	*Total*
Contributes to a positive driving experience	2 (0%)	5 (1%)	35 (8%)	83 (18%)	169 (37 %)	294 (64%)
Keeps the car in middle of lane	3 (1%)	4 (1%)	31 (7%)	69 (15%)	149 (32%)	256 (56%)
Been helpful in dangerous situations	0 (0%)	0 (0%)	12 (3%)	28 (6%)	66 (14%)	106 (23%)
Increases risk to be in dangerous situations	1 (0%)	0 (0%)	1 (0%)	6 (1%)	15 (3%)	23 (5%)
Have good understanding of function of system	3 (1%)	4 (1%)	36 (8%)	107 (23%)	228 (49%)	378 (82%)
Is easy to use	3 (1%)	5 (1%)	38 (8%)	106 (23%)	223 (48%)	375 (81%)
Fights against the system	2 (0%)	0 (0%)	2 (0%)	9 (2%)	19 (4%)	32 (7%)
Feels to disconnected from driving the car	0 (0%)	0 (0%)	3 (1%)	6 (1%)	15 (3%)	24 (5%)

Table 21 Ability to use ACC on different types of roads and traffic enviroments versus driving frequencies

Type of road	*Some occasions a year*	*Some occasions a month*	*An occasion a week*	*At least three days a week*	*Every day*	*Total*
Country roads	7 (1%)	19 (2%)	110 (11%)	241 (24%)	536 (53%)	913 (91%)
Citystreets	2 (0%)	7 (1%)	47 (5%)	100 (10%)	212 (21%)	368 (37%)
Highway roads	8 (1%)	20 (2%)	116 (12%)	251 (25%)	573 (57%)	968 (97%)
Roads with separated lanes (2+1 lanes)	7 (1%)	17 (2%)	99 (10%)	219 (22%)	491 (49%)	833 (83%)
Winding roads	3 (0%)	2 (0%)	34 (3%)	78 (8%)	199 (20%)	316 (32%)
Roads with traffic lights and/or traffic circle	1 (0%)	4 (0%)	24 (2%)	56 (6%)	144 (14%)	229 (23%)

Table 22 Ability to use LKA on different types of roads and traffic environments versus driving frequencies

Type of Road	*Some occasions a year*	*Some occasions a month*	*An occasion a week*	*At least three days a week*	*Every day*	*Total*
Country roads	1 (0%)	4 (1%)	44 (10%)	108 (23%)	218 (47%)	375 (81%)
Citystreets	1 (0%)	1 (0%)	14 (3%)	29 (6%)	68 (15%)	113 (25%)

Highway roads	3 (1%)	4 (1%)	41 (9%)	117 (25%)	240 (52%)	405 (88%)
Roads with separated lanes (2+1 lanes)	2 (0%)	3 (1%)	33 (7%)	98 (21%)	185 (40%)	321 (70%)
Winding roads	1 (0%)	1 (0%)	14 (3%)	33 (7%)	69 (15%)	118 (26%)
Roads with traffic lights and/or traffic circle	0 (0%)	0 (0%)	6 (1%)	18 (4%)	41 (9%)	65 (14%)