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Chinese Drivers' Attitudes Toward Level 2+ Driving Automation

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ABSTRACT

In addition to SAE 6 levels of driving automation, the industry has introduced Level 2+ driving automation (L2+), which includes features such as Highway Driving Pilot (HDP), Automatic Parking Assist (APA), Valet Parking Assist (VPA) and Remote Parking Assist (RPA). A mixed-methods study was conducted to investigate the daily usage and attitudes of L2+ experienced drivers toward L2+ features. 395 L2+ experienced drivers in China participated in the on-line survey, and 11 of them joined successive validation interviews. The results show that HDP and APA are the most commonly used features. Drivers experience more fun with tech from using parking features, while HDP provide users with relaxing time. Safety concerns are the main reason why drivers do not use L2+ features, which in turn decreases usage and negatively correlates with performance-related reasons for not using them. These findings suggest that drivers hold divergent attitudes towards L2+ features, with a focus on safety or efficiency. Such findings can guide product design and customer education.

Keywords: Highway driving pilot, Automatic parking assist, Driving automation, Customer attitudes

INTRODUCTION

In partnership with the International Organization for Standardization (ISO), Society of Automotive Engineers (SAE) recommended 6 levels of driving automation, from Level 0 (no driving automation) to Level 5 (full driving automation) for motor vehicles and their operation on roadways (Society of Automotive Engineers, 2021).

China is currently in the process of transitioning from Level 2 (L2) to Level 3 (L3), and high customer acceptance is an essential requirement for new products to enter the market. There has been a certain accumulation of research results related to L2 and L3 user acceptance in both domestic and foreign research.

Public Acceptance

Previous research has indicated that drivers generally hold a high level of trust in valid L2 features. In a study conducted by Nordhoff et al. (2021) investigating attitudes towards L2 driving automation, it was found that drivers placed a high level of trust in vehicle speed and distance

maintenance features. However, compared to manual driving, partial automation did lead to increased engagement in secondary tasks such as observing the landscape. Additionally, the study found that performance expectation was the most influential factor in determining drivers' use of assisted driving systems. In another study by Wilson et al. (2007), lane departure was reduced by 10%-60% with the use of Adaptive Cruise Control (ACC), and drivers' acceptance of this technology was consistently high.

As drivers begin to interact with L3 features, their concerns tend to increase. According to a study of user attitudes and preferences towards L2 to L5, the largest disparity in attitudes and preferences exists between L2 and L3, and safety is the most significant factor of the decline (Lajunen and Sullman, 2021). This further indicates that L3 driving automation is in the watershed between human and machine-led driving, which puts forward higher demands for man-machine co-driving.

Despite the concerns regarding L3 driving automation, there is still a positive public acceptance towards higher level driving automation applications. Li et al. (2020) conducted a study on 64 published studies related to autonomous driving public acceptance and identified five major topics: technology acceptance, trust, perception, payment willingness, and usage preferences. The study showed an overall positive public acceptance towards autonomous driving. Trust building is also considered essential for higher level driving automation. Researchers suggest that improving system transparency, technical competence, and situation management could positively affect trust towards L3 automated vehicles and result in increased willingness to use L3 automated vehicles (Choi and Ji, 2015) as well as L5 autonomous vehicles (AV) (Choi and Ji, 2015; Xu et al., 2018).

L2+ Features

SAE Level 2 driving automation features provide support to the driver in steering and brake/acceleration control. Lane Centering Control (LCC) with Adaptive Cruise Control (ACC) is a common L2 feature found in private cars. According to IDC, the penetration rate of L2 autonomous driving in China's passenger car market reached 23.2% in the first quarter of 2022 (IDC, 2022).

On the road to highly automated driving, the industry introduced L2+ features to the market (Mobileye, 2020; Brooke, 2020). The term L2+ was first introduced by Mobileye at the CES in 2018. Mobileye's L2+ technology adds its Road Experience Management maps to L2 solutions, which enables pseudo-autonomy (Mobileye, 2020) and avoids the cost, complexity and uncertainty of L3 (Brooke, 2020). According to Mobileye's explanation for L2+ and Manufactures' introduction, we can observe 4 major features of L2+ assisted driving in China market: highway driving pilot (HDP) (Shujubang.com, 2022), automatic parking assist (APA), valet parking assist (VPA) (Research and Markets, 2021) and remote parking assist (RPA) (Tesla, 2020; Xpeng, 2020). The descriptions and representative applications of these 4 features are shown in Table 1.

From 2022 Q1 to Q3, L2+ feature load rate reaches 5.1% in China passenger car market, forcasted to surpass 15% in 2025 (Shujubang.com, 2022).

Table 1. 4 major L2+ features.

Feature name	Feature description	Representative applications
Highway Driving Pilot (HDP)	The vehicle can drive automatically in the highway pilot map area, controlling its speed, space and lane choice.	Tesla NOA, Xpeng NGP, NIO NOP
Automatic Parking Assist (APA)	The vehicle can detect nearby parking space and park itself.	Tesla Autopark, Xpeng APA, ArcFox APA, BYD APA
Valet Parking Assist (VPA)	The vehicle can remember parking routes in a mapped area and drive the routes automatically.	Xpeng VPA, Weltmeister AVP
Remote Parking Assist (RPA)	Under the control of a phone app or a key outside, the vehicle can move in a certain route slowly.	Tesla Smart Sumon, Xpeng RPA

The industry strives to evolve from L2 to higher lever driving automation and pioneering customers also pay for this new trend, providing study opportunities for research. This study aims to explore how drivers actually use L2+ features, as well as their reasons for using or not using them. By investigating customer attitudes in this area, we can gain valuable insights into the adoption of higher-level driving automation.

METHOD

Questionnaire Survey

A questionnaire was placed in Baidu Map, CarLife for 2 weeks. Baidu Map is a popular travel assistance APP proceeding billions of service requests daily (Baidu Map, 2020). CarLife is a Baidu-owned screen casting app that requires binding with the vehicle, so drivers are the main users (Baidu CarLife+, 2020). Samples were filtered with lie detection questions. For example, Tesla samples who choosing VPA were deleted. Finally, 973 valid data were obtained, including 395 with L2+ experience and 578 with no L2+ experience. The questionnaire also included demographic information: gender, age and driving experience. 91.26% of drivers who participated in the questionnaire were male and 8.74% were female. Most of them were over 30 years old, accounting for 77.7%. Drivers with more than 3 years driving experience accounted for 78.21%.

This section includes the usage frequency of each feature and why it is used/not used. Options are summarized by consulting relevant practitioners. Reasons of using/not using can be multiple-chosen in the questionnaire, with the options appearing in random order (see Table 2). For drivers who had not used L2+ features, general views on HDP and APA was asked.

User Interview

11 questionnaire participants with high L2+ functional attempts were selected for further remote interviews (see Table 3). The interviews are intended to validate questionnaire information.

Table 2. Reasons of using/not using in the questionnaire.

Reasons of using	Reasons of not using
Interest in technology	Low success rate/ Need to take over frequently
Relax and rest	Safety concern
Use the time to do other things	Difficulty in learning/operating
Lack of driving pleasure	Drive slower than you do
Save time	Drive worse than you do
Drive better than you do	Need to change lane (HDP)
All drivers use it	No fixed parking space (VPA/RPA)
Other	Other

Table 3. Basic information of 11 drivers in user interview.

No.	Gender	Age	Occupation	L2+ Features Weekly Use Frequency	Driving Experience (year)
1	male	28	Service industry employee	>7	>3
2	male	26	Internet industry employee	1–3	>3
3	male	28	Watch industry staff	>7	>3
4	male	37	State-owned enterprises employee	>7	1-3
5	male	31	Media entrepreneur	>7	>3
6	male	28	Employee of public institution	4–7	>3
7	male	38	University staff	4–7	>3
8	male	35	Educational industry employee	1–3	>3
9	male	21	Automobile industry employee	4–7	2
10	male	34	Civil professional	1–3	>3
11	male	32	Administrative assistant	4–7	>3

RESULT

Usage of L2+ Features

Table 4 shows the proportion of different L2+ feature usage. The most experienced feature is HDP, 57.47% of all L2+ drivers tried. APA function was the next, accounting for 51.14% of all L2+ drivers. VPA and RPA were experienced by significantly fewer people, accounting for 16.20% and 18.99% respectively.

HDP and APA were most common features in these L2+ features, 78 drivers experienced both HDP and APA, with an overlap of 19.75% of all population. As for both parking assistance features, 28 people experienced

Table 4. Proportion of use of L2+ features.

Options-multiple choice	n	Proportion of All	Proportion of L2+
Highway Driving Pilot (HDP)	227	23.33%	57.47%
Automatic Parking Assist (APA)	202	20.76%	51.14%
Valet Parking Assist (VPA)	64	6.58%	16.20%
Remote Parking Assist (RPA)	75	7.71%	18.99%
None of above[a]	578	59.40%	

[a]Mutually exclusive with other options

both VPA and APA, accounting for 7.09%. 49 people experienced both RPA and APA, accounting for 12.15%.

In terms of usage frequency (see Table 5), most drivers only tried several times. The proportion of getting into the habit of using HDP (more than once a week) was the highest, accounting for 42.29%. APA followed with 36.63%, while RPA was 34.67%. VPA had the lowest number of users and a lower regular using rate of 28.12%. In general, the frequency of regular use did not exceed the half.

Proportion of Using/Not Using Reasons Selected

The main reason for using parking assistance features was interest in technology, 74.26% for APA, 71.88% for VPA and 70.67% for RPA, shown in Table 6. HDP could make drivers feel relaxed, selecting by 69.16% of whom experienced this feature.

Table 7 represents main reasons of not using was safety concerns. For HDP, the second reason was take-over problems (37.44%) and need to change lane (35.24%). APA completed fewer driving actions and, apart from safety concerns (63.86%), the most prominent problem was driving slower (41.09%), followed by low success rate (32.18%). Relatively less safety concerns in using VPA (59.38%) and RPA (54.67%) and more worries in performance. 29.69% VPA users reported take over frequently problem and 29.33% RPA users complained slow-driving of the system.

Correlation Analysis of HDP Using/Not Using Reasons

With over 200 drivers using HDP and APA, the relationship between the use/not-using reasons was further analyzed with Kendall nonparametric correlation analysis (Croux and Dehon, 2010).

Table 5. Usage frequency of L2+ features.

Options-multiple choice	n	Used several times	1-3 per week	4-7 per week	>7 per week
Highway Driving Pilot (HDP)	227	57.71%	30.40%	6.61%	5.29%
Automatic Parking Assist (APA)	202	63.37%	23.27%	8.42%	4.95%
Valet Parking Assist (VPA)	64	71.88%	17.19%	6.25%	4.69%
Remote Parking Assist (RPA)	75	65.33%	24.00%	9.33%	1.33%

Table 6. Reasons of using among L2+ features.

Reasons of using-multiple choice	HDP n = 227	APA n = 202	VPA n = 64	RPA n = 75
Interest in technology	49.78%	74.26%	71.88%	70.67%
Relax and rest	69.16%	38.12%	57.81%	34.67%
Use the time to do other things	21.59%	17.33%	25.00%	16.00%
Lack of driving pleasure	17.62%	14.85%	25.00%	13.33%
Save time	14.54%	14.36%	23.44%	18.67%
Drive better than you do	23.35%	22.28%	17.19%	14.67%
All drivers use it	3.96%	4.95%	10.94%	2.67%
Other	5.29%	5.94%	0.00%	8.00%

Table 7. Reasons of not using among L2+ features.

Reasons of using-multiple choice	HDP **n = 227**	APA **n = 202**	VPA **n = 64**	RPA **n = 75**
Low success rate		32.18%	34.38%	34.67%
Need to take over frequently	37.44%		29.69%	
Safety concerns	69.16%	63.86%	59.38%	54.67%
Difficulty in learning/operating	12.33%	11.39%	17.19%	17.33%
Drive slower than you do	13.22%	41.09%	20.31%	29.33%
Drive worse than you do	10.57%	12.87%	9.38%	13.33%
Need to change lane (HDP)	35.24%			
Lack of fixed parking space (VPA/ RPA)			21.88%	21.33%
Other	6.61%	4.46%	1.56%	1.33%

Table 8. Correlation between usage frequency of HDP and reasons of using.

Reasons of using HDP	**Frequency**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1: Interest in technology	−0.01							
2: Relax and rest	−0.03	−0.04						
3: Use the time to do other things	0.09	0.08	0.00					
4: Lack of driving pleasure	0.02	−0.09	−0.02	0.07				
5: Save time	0.07	−0.06	−0.13*	0.03	0.01			
6: Drive better than you do	0.03	−0.01	−0.08	−0.01	0.10	0.27**		
7: All drivers use it	−0.03	0.02	−0.06	0.06	0.02	0.11	0.15*	
8: Other	−0.06	−0.12	−0.14	0.02	−0.11	−0.10	−0.13	0.05

**$p<0.01$; *$p<0.05$

Table 9. Correlation between usage frequency of HDP and reasons of not using.

Reasons of using HDP	**Frequency**	**1**	**2**	**3**	**4**	**5**	**6**
1: Need to take over frequently	−0.02						
2: Safety concern	−0.15*	−0.07					
3: Difficulty in learning/operating	0.05	−0.04	−0.13				
4: Drive slower than you do	0.04	−0.09	−0.16*	0.05			
5: Drive worse than you do	−0.06	0.06	−0.02	−0.04	0.16		
6: Need to change lane	0.09	−0.08	−0.05	−0.14*	−0.02	0.11	
7: Other	0.06	−0.17*	−0.24**	0.01	−0.05	−0.09	−0.05

**$p<0.01$; *$p<0.05$

Table 8 shows no significant correlation between usage frequency of HDP and reasons of using. "Save time" was negatively correlated with "Relax and rest" ($r = -0.13$, $p < 0.05$). "Driving better than you do" is positively correlated with "Save time" (r=0.27, $p < 0.01$) and "All drivers use it" ($r = 0.15$, $p < 0.05$).

Table 9 represents a significant negative correlation between the usage frequency of HDP and "Safety concern". As the main reason of not using, "Safety concern" was significantly negatively associated with "Driving slower" ($r = -0.16$, $p < 0.05$) and "Other" ($r = -0.24$, $p < 0.01$). And "Other" was negatively associated with "Need to take over frequently" ($r = -0.17$, $p < 0.05$). "Difficulty in learning/operating" was also negatively correlated with "Need to change lane" ($r = -0.14$, $p < 0.05$)

Overall, safety concerns have dampened the usage frequency of HDP. Safety preference and efficiency preference are slightly separated.

Correlation Analysis of APA Using/Not Using Reasons

Table 10 shows that the usage frequency of APA was positively correlated with "Relax and rest" ($r = 0.21$, $p < 0.01$), "Use the time to do other things" ($r = 0.14$, $p < 0.05$) and "Save time" ($r = 0.17$ $p < 0.05$). "Use the tine to do other things" is positively correlated with "Relax and rest" ($r = 0.18$, $p < 0.05$) and "Lack of driving pleasure" ($r = 0.25$, pt̃extless 0.01), and "Save time" is positively correlated with "Lack of driving pleasure" ($r = 0.27$, $p<0.01$) and "Drive better than you do" ($r = 0.46$, $p < 0.01$). "Interest in technology" is negatively correlated with "Other" ($r = -0.28$, $p < 0.01$).

Table 11 shows no significant correlation between usage frequency of APA and reasons of not using. As the main reason of not using, "Safety concern" was significantly negatively correlated with "Drive slower than you do"($r = -0.31$ $p < 0.01$) and "Other"($r = -0.24$, $p < 0.01$). "Drive slower than you do" had a significantly positive correlation with "Drive worse than you do"($r = 0.22$, $p < 0.01$). There is a considerable difference between safety preference and efficiency preference in the reasons of not using APA.

L2+ Non-Use Drivers' Attitude

For drivers who had not used L2+ features, there were 74.40% concerned about HDP and 66.60% concerned about APA. Among them, 49.31% said they expected to use HDP and 43.94% expected to use APA. Overall, L2+ features are attracting the attention of drivers.

Users Interview Validation

The questionnaire responses from the 11 users shown in Table 3 were generally consistent with the interview validation. 2 users gave slightly different

Table 10. Correlation between usage frequency of APA and reasons of using.

Reasons of using APA	Frequency	1	2	3	4	5	6
1: Interest in technology	−0.03						
2: Relax and rest	0.21**	−0.12					
3: Use the time to do other things	0.14*	0.06	0.18*				
4: Lack of driving pleasure	−0.02	−0.01	0.10	0.25**			
5: Save time	0.17*	−0.15	0.06	0.07	0.27**		
6: Drive better than you do	0.12	−0.09	−0.03	0.07	0.11	0.46**	
7: All drivers use it	−0.03	−0.07	0.10	0.02	−0.03	0.10	0.15
8: Other	−0.12	−0.28**	−0.11	−0.12	−0.10	−0.10	−0.13

**$p<0.01$; *$p<0.05$

Table 11. Correlation between usage frequency of APA and reasons of not using.

Reasons of not using APA	Frequency	1	2	3	4	5
1: Low success rate	−0.07	1.00				
2: Safety concern	−0.15	−0.12	1.00			
3: Difficulty in learning/operating	0.05	−0.01	−0.12	1.00		
4: Drive slower than you do	−0.04	0.01	−0.31**	−0.05	1.00	
5: Drive worse than you do	0.05	−0.01	−0.11	0.09	0.22**	1.00
6: Other	0.06	−0.05	−0.24**	−0.08	−0.13	−0.08

** $p<0.01$; *$p<0.05$

feedbacks. User No. 4 reported "no usage" in the questionnaire because of low success rate of VPA. User No. 11, who used APA at a moderate frequency, abandoned it later because of low success rate and slow parking speed.

HDP requires a lot of attention to observe the vehicle even when it is on autopilot because of safety concern in the highway scenes. User No. 1 shared that he could chat with accompanying people and User No. 11 thought it's better keep focus on driving. Other users participated in the interview part gave similar feedbacks.

APA and VPA have slow speed, allowing users to take breaks and do activities like tuning music, packing belongings and replying to messages. Most users agreed with that except User No.7 and User No.11. They argued that checking vehicle status at the same time is important.

DISCUSSION

Road to Higher Automation

Although the public generally welcome the higher level of driving automation, it's expensive to in terms of large-scale manufacturing. L2+ approach gives a quick and economical trial to private car market. The responses from actual users confirmed that this approach is accepted by pioneering customers, influencing potential buyers. However, safety uncertainty has not solid solved yet in this phase. Safety concerns depressed the usage of HDP significantly where APA usage frequency was not affected. This suggests that APA and other slow-speed automation, i.e., VPA, may be a more promising option to try higher level of driving automation.

Safety-Sensitive & Efficiency-Sensitive

For practitioners, safety and efficiency are often in conflict. The slower the system moves in the self-driving phase, the easier it is to ensure safety and allow drivers to take over in time. However, it's not always the same case. Sometimes drivers quit using because of lacking efficiency. In this study, we found HDP tend to be safety-sensitive. Safety concern is significant negatively correlated with usage frequency, and also negatively correlated with driving slow. APA tend to be efficiency-sensitive. In interview part, participants reflected APA and VPA gave them convenience to do other things, which improved the everyday parking experience. The opportunity of relax, dealing other things simultaneously and saving time attracts drivers to try APA function. These results might be hint for manufactures to carefully design different driving styles regarding to the specific scene.

Limitations & Future Work

This study is intended to get a general image of nowadays L2+ users. To dig into acceptance and experience evaluation models, more extended and structured following studies could be applied. Also, the comparison of actual users and other population could be examined via future studies. For example, the safety uncertainty perception difference between long-time

L2+ feature users and the public. These potential study topics will give references for policy makers, manufactures and the public.

CONCLUSION

The study investigates influential factors of the actual usage of L2+ assisted driving. Drivers are safety-sensitive when using HDP. Safety concern hindered HDP usage frequency. While parking assist features, such as APA, are more efficiency-oriented, as drivers use them to save time and multitask. Therefore, we recommend different driving-style-scene design tactics for practitioners to tailor into actual L2+ drivers' demand.

REFERENCES

Baidu CarLife+. (2020). I'm CarLife+ [Online]Available: https://online.carlife.baidu.com/ [Accessed December 19, 2022].

Baidu Map. (2020). Business Cooperation Center. [Online]Available: https://map-hz.baidu.com/ [Accessed December 19, 2022].

Brooke, Lindsay. (2020). 'Level 2+': Making automated driving profitable, mainstream. [Online]. SAE. Available: https://www.sae.org/news/2020/12/rise-of-sae-level-2 [Accessed January 16, 2023].

Choi, Jong Kyu. Ji, Yong Gu (2015). Investigating the importance of trust on adopting an autonomous vehicle. International Journal of Human-Computer Interaction, 31(10), pp. 692–702.

Croux, Christophe. Dehon, Catherine (2010). Influence functions of the Spearman and Kendall correlation measures. Statistical methods & applications, 19, pp. 497–515.

IDC. (2022). Q1 passenger car L2 penetration reaches 23.2%. [Online] Available: https://www.idc.com/getdoc.jsp?containerId=prCHC49058722 [Accessed December 19, 2022].

Lajunen, Timo. Sullman, Mark JM (2021). Attitudes toward four levels of self-driving technology among elderly drivers. Frontiers in psychology, 12, p. 682973.

Li, Tang, et al. (2020). Research review on public acceptance of autonomous driving. Journal of Traffic and Transportation Engineering, 20, pp. 131–146.

Mobileye. (2020). Understanding L2+ in five questions. [Online] Available: https://www.mobileye.com/blog/understanding-l2-in-five-questions/ [Accessed December 20, 2022].

Nordhoff, Sina. Stapel, Jork. He, Xiaolin, et al. (2021). Perceived safety and trust in SAE Level 2 partially automated cars: Results from an online questionnaire. Plos one, 16, e0260953.

Research and Markets. (2021). China Automated Parking Assist (APA) and Automated Valet Parking (AVP) Market Report 2021–2023. [Online] Available: https://www.globenewswire.com/en/news-release/2021/06/09/2244115/28124/en/China-Automated-Parking-Assist-APA-and-Automated-Valet-Parking-AVP-Market-Report-2021-2023.html.

Shujubang.com. (2022). 2022 China Passenger Car L2 &L2+ Driving Automation Report. [Online]. Available: https://db.shujubang.com/home/login/index/gid/18833 [Accessed December 18, 2022].

Society of Automotive Engineers. (2021). Taxonomy and definitions for terms Related to driving automation systems for on-road motor vehicles. [Online] Available: https://doi.org/10.4271/J3016_202104

Tesla. (2020). Model S Owner's Manual-Smart Summon. [Online]. Available: https://www.tesla.com/ownersmanual/2012_2020_models/zh_cn/GUID-6B9A1AEA-579C-400E-A7A6-E4916BCD5DED.html [Accessed December 19, 2022].

Wilson, Bruce, et al. 2007. Evaluation of a Road-Departure Crash Warning System. United States. National Highway Safety Bureau.

Xpeng. (2020). G3 Instruction Book-Remote Parking. [Online]. Available: https://www.xiaopeng.com/instruction_book/758?type=page [Accessed December 19, 2022].

Xu, Zhigang. Zhang, Kaifan. Min, Haigen, et al. (2018). What drives people to accept automated vehicles? Findings from a field experiment. Transportation Research Part C: Emerging Technologies, 95, pp. 320–334.