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Cross-Cultural Analysis of Young Drivers' Preferences for In-Vehicle Systems and Behavioral Effects Caused by Secondary Tasks

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Abstract: Hundreds of new features and functionalities have been introduced as in-vehicle systems (IVS) mature. However, it remains unclear whether these novel designs have appropriately addressed driver preferences and requirements, especially when factors such as geographical or cultural differences are considered. An empirical study was conducted to determine cultural differences between young Chinese and German drivers with respect to (a) preferences for 18 selected IVS and (b) behavioral effects in six secondary driving tasks. Data from 232 Chinese and 94 German drivers were collected through an online questionnaire and the results indicate that young Chinese drivers value most of the selected IVS designs more significantly than the Germans do, except in categories such as radio, navigation and autonomous emergency braking. In addition, rotary with a display screen is the most preferred interaction modality for both groups. As for behavioral effects when performing secondary tasks, young Chinese drivers are more likely to engage in safety-related scenarios while the Germans in efficiency-related scenarios. An ordinal logistic regression analysis suggested a strong correlation between secondary tasks (looking up navigation, dialing the phone and connecting Bluetooth) and behavioral degradation for young Chinese drivers, whereas the six secondary tasks seem to affect German drivers minimally. Based on the preference analysis and attitudes to behavioral impacts, implications for the design of IVS are discussed to better satisfy needs from drivers of different cultural backgrounds.

Keywords: cross-cultural analysis; in-vehicle systems; interaction modality; secondary tasks; behavioral effects

1. Introduction

Driving is a sophisticated and safety-critical process with multiple tasks. The primary tasks require drivers to take good control of the vehicle by accelerating, braking, steering and detecting hazards [1]. Besides the primary tasks, any other activities performed during driving are identified as secondary tasks such as using audio-visual systems [1]. Secondary tasks aim to enhance the driving experience by offering an entertaining and comfortable environment instead of ensuring driver safety. To make different secondary tasks easy to access and operate, An In-Vehicle Information System (IVIS) as a menu-based system was designed to integrate secondary tasks into the system, rendering IVIS interaction a secondary task. However, secondary tasks require drivers' attention away from road traffic to perform certain activities, thus, impairing the drivers' ability of hazard detection and vehicle control. An Advanced Driver Assistance System (ADAS) was developed to address this problem by strengthening longitudinal/lateral control, monitoring driver state and avoiding hazardous scenarios [2]. In some cases, the ADAS will assume vehicle control to avoid collisions when

it reaches a critical point [3]. Overall, the available and applicable In-vehicle System (IVS) on the auto market contains two different types of systems (IVIS and ADAS) and they have distinct effects on driving performances. Moreover, current research has focused more on secondary tasks. Naturalistic data has indicated that 'just driving' without conducting any secondary tasks only accounts for 46% of the overall driving time [4]. Similarly, Farmer [5] observed a random sample of 108 drivers for one year and found that these drivers spent 42% of their driving time conducting at least one secondary task. However, secondary tasks present much more distraction and hazards besides the entertaining driving experiences. It has been reported that driver distraction out of secondary tasks is related to over 22% crashes/near-crashes [6,7].

Numerous past studies have attempted to explore the relationship between driver behavior and secondary tasks and most of them were accomplished via driving simulators. For example, Tsimhoni [8] investigated how different input methods (speech and typing) of address entry affected driver behavior and found out that typing evidently increased lateral deviation, while speech also resulted in degradation of vehicle control. Lee [9] pointed out that when using an MP3 player and searching through long playlists, drivers' attention was greatly affected that their eyes-off-road exceeded 2 s, which was a suggested maximum time [10]. In addition, Chisholm [11] discovered that manipulating an MP3 player increased drivers' reaction time to hazards and collisions. Haque and Washington [12] indicated that drivers tended to brake more aggressively and abruptly when conversing on the phone. Collet [13] made a comprehensive exploration of how phoning would impact driver performances and discovered that information processing (e.g., reaction time) and vehicle control (e.g., lane-keeping or speed) were the most impaired abilities. Furthermore, texting was also distracting and interfered with the longitudinal and lateral control resulting in a higher likelihood of being involved in an accident [14,15]. Besides driving simulators, instrumented vehicles are utilized to investigate the behavioral impairment out of secondary tasks. Similar results were found that both entering navigation addresses or texting messages severely degraded drivers' ability of risk perception and vehicle control [16,17]. Additionally, questionnaires provided a subjective evaluation of drivers' risk perception. By using a driver behavior questionnaire, Zhao [18] found that frequent phone use was related to more involvement in risky driving behavior such as speeding and traffic lights violation. Drivers in New Zealand were confronted with the same problem and they were less aware of the risks when talking on the phone [19]. Overall, these studies revealed that once drivers were engaged in a secondary task, their performances could be strongly impacted in spite of how they performed these tasks. In general, the degradation of driver behaviors was reflected in an increase of reaction time to hazards, braking times and errors, lateral deviation and longer glances away from roadway [12,20,21]. Cunningham [22] carried out a thorough discussion of previous studies and presented the most common secondary tasks (e.g., manipulating radio, CD, DVD, navigation and cell phones) and how driver behaviors (e.g., information processing and vehicle control) were impaired under each task.

Researchers have paid attention to the design of IVS and investigated the applicability of IVS for drivers from different cultural backgrounds. Knapp [23] made a comparison between German and Chinese drivers regarding the navigation system and found that if the system was designed based on the mental model of German culture, Chinese drivers suffered performance impairments. The task completion time increased and unnecessary steps were taken while interacting with the system and vice versa. Heimgärtner [24,25] discovered that Chinese drivers were inclined to carry out multiple tasks simultaneously when compared to German drivers and seemed to favor a higher information speed and density. Young [26] investigated the preferences for the design of IVIS between Chinese and Australian drivers and pointed out that the introduction of IVIS from western markets into China could be problematic without alteration. Lindgren [27] explored what ADAS functions should be introduced into the Chinese auto market and how Chinese drivers valued these systems. He concluded that the ADAS functions designed for Sweden drivers were not necessarily optimal for Chinese drivers. Moreover, Olaverri-Monreal [28] compared drivers' preferences for specific IVIS functions among

users from Germany, USA and Japan and confirmed the existence of cultural differences. For example, German drivers value the radio much more than the other groups.

However, there are some gaps in these past and on-going studies. Firstly, though a range of studies have been dedicated to secondary tasks and the negative impacts, very few researchers paid attention to a cross-cultural analysis. Secondly, current cross-cultural studies regarding IVS functions mainly focus on the design (label, color and information presentation style) and are built on the premise that that IVS functions are accepted by local drivers. However, if drivers do not perceive the functions important in the first place, their preferences for the design may seem perplexing and unable to meet the research objectives. Accordingly, a thorough discussion on drivers' perception of the importance of common IVS functions is needed. Moreover, the subjects of cross-cultural studies include drivers of all ages, yet age can be a potential impact on the design of IVS functions. Young and elder drivers may have distinct attitudes towards IVS units. Particularly, young drivers have a keen sensitivity to innovative technologies. For example, it has been reported that 98% of young drivers have texted while driving [29], which becomes a universal issue in the US [30], Australia [31], and New Zealand [32]. Compared with older drivers, young drivers do not only text but they also show more interests in other secondary tasks such as manipulating music devices, dialing the phone and even sending emails [33]. Additionally, young drivers are more likely to involve in risky driving behaviors and commit more road violations than their older counterparts when performing secondary tasks [34–36]. In middle-income countries, young drivers aged 15–29 years cause the majority of crashes and fatalities [37]. As a result, the study of young drivers is of great significance.

According to the China Association of Automobile Manufacturers (CAAM), German-branded cars stood in the first place as the most sold foreign cars in China since 2012 and reached over 4.8 million shipments in 2017. Moreover, some local auto manufacturers learn from the IVS design from German cars, which results in more and more Chinese drivers being exposed to such systems. Yet, whether the IVS design of German cars accords with the preferences of Chinese drivers remains unknown. To understand if the cultural differences in IVS preferences are beneficial to the development of these systems for both domestic and abroad manufacturers. The present study attempts to bridge the gaps and addresses two research questions: (a) How do young Chinese and German drivers perceive the importance of certain IVS functions (IVIS and ADAS), and (b) how do they estimate the behavioral impairment out of secondary tasks.

2. Methodology

2.1. Questionnaire Design

Before presenting the questionnaire, we clarified several technical terms for the participants, (a) the definition of IVS, IVIS and ADAS, as well as secondary tasks and (b) the definition of interaction modality and different types such as knobs, touchscreen and voice control. Drivers were eligible to participate in this study if they owned a car. Additionally, a drivers' familiarity with IVS was examined with a five-point scale measurement from 1 to 5 (not at all familiar to extremely familiar). The questionnaire was divided into three major sections as follows.

2.1.1. General Information

Section one measured the demographics of the participants, including gender, age and driving experience.

2.1.2. Preferences for In-Vehicle Systems and Interaction Modality

In the second part, drivers' preferences for 18 selected IVS (10 IVIS and 8 ADAS) were evaluated first by asking 'how important do you perceive the following in-vehicle systems'. The five-point scale measurement was applied (1 to 5; not at all important to extremely important). According to several existing driver information systems e.g., COMMAND of Mercedes, InTouch of Infiniti and Version of

Tesla, 10 of the most popular and common IVIS functions were picked out consisting of radio, media, telephone, navigation, parking information (parking), Bluetooth, air conditioning (AC), weather, driving mode and settings. Eight common ADAS functions from the following three categories were selected: longitudinal assistances (adaptive cruise control (ACC), forward collision warning (FCW) and autonomous emergency braking (AEB)), lateral assistances (lane departure warning (LDW) and lane change assist (LCA)), other assistance (rear view radar/camera (RV), night vision system (NVS) and tire pressure monitoring system (TPMS)). For each in-vehicle system, participants received a brief introduction.

In addition, participants were asked about their preferences on interaction modalities. Four of the most popular modalities were given as options: knobs, touch screen, rotary with a display screen and voice control.

2.1.3. Behavioral Effects in Secondary Tasks

Section three attempted to investigate the relationship between secondary tasks and driver behavior. Firstly, to determine the behavioral degradation caused by secondary tasks, eight hazardous scenarios were depicted as presented in Table 1. These scenarios contained safety-related situations, e.g., conflicts with vehicles and vulnerable road users as well as efficiency-related situations (misinterpretation of traffic signs). Participants were asked 'how frequently do you encounter the following scenarios when performing a secondary task', and had to choose between 1-never, 2-seldom, 3-sometimes, 4-often and 5-very often.

We examined 'what secondary tasks they were engaging with when confronting a hazardous situation' using a multiple-choice question. Six of the most common secondary tasks were included: playing music, looking up navigation, dialing phone, looking up for information, setting up air conditioning (AC) and connecting Bluetooth.

Table 1. Eight critical scenarios in an urban traffic environment.

Scenarios	Description
Scenario 1 (S1)	Sudden braking (lack of attention to deceleration of vehicles ahead)
Scenario 2 (S2)	Sudden braking (lack of attention to cutting-in vehicles)
Scenario 3 (S3)	Hitting/nearly hitting pedestrians/bicyclists
Scenario 4 (S4)	Running/nearly running the traffic lights
Scenario 5 (S5)	Honked by other vehicles after the traffic lights turn green
Scenario 6 (S6)	Entering wrong lanes when approaching the intersections
Scenario 7 (S7)	Deviating from current lane
Scenario 8 (S8)	Misinterpreting /overlooking traffic signs

2.2. Procedure

The questionnaire was generated on a widely-used survey platform (https://www.wjx.cn/) in China. The questionnaire was distributed via email to 224 faculty members of the School of Mechanical Engineering in the Beijing Institute of Technology. The survey platform could also generate web links and QR codes for SNS platforms such as WeChat and Weibo, allowing us to involve more participants in this research. Once participants finished the questionnaire, the data would be collected on this platform.

For the investigation of German drivers, the questionnaire was designed through Google Chart and distributed via email to 47 faculty members of the Chair of Ergonomics at the Technical University of Munich. Furthermore, we printed 100 hard copies and distributed them on the university's campus.

2.3. Participants

In total, 531 Chinese drivers participated in this research. Considering the requirement, 53 drivers did not own a car but have rented one before. Moreover, 48 responses were found with an unusual answering time (less than 100 s or more than 500 s) and some of them answered the survey more than once. Among the 430 valid questionnaires, 278 (64.6%) were from young drivers between the age of 18–30 years, which was the research focus in this study. This age group was chosen in accordance with the report of the WHO [36] and 18 being the minimum age for a driver license. In addition, familiarity with IVS was explored and 46 participants reported their unfamiliarity. Overall, 232 valid questionnaires were sorted out with drivers between 18–30 years.

114 questionnaires were collected from German drivers (all participants reported to own a car). However, 16 respondents were unfamiliar with IVS, thus, their data were disregarded. Overall, 94 participants in the age group 18–30 years completed the questionnaire. Table 2 shows the general information of respondents.

Table 2. Participant Demography.

Group	Number	Gender	Mean Driving Experience (sd [2]) in Years
Chinese	232	176 M/56 F [1]	2.78 (1.14)
German	94	68 M/26 F [1]	3.22 (1.11)

[1] M = male, F = female. [2] sd = standard deviation.

3. Results

Statistical Product and Service Solutions (SPSS) was employed for data evaluation. Addressing the first research question, our hypothesis was that there were significant differences between young Chinese and German drivers regarding the importance ratings of IVS. With respect to the second research question, we hypothesized that secondary tasks imposed negative impacts on driver behavior in both groups.

3.1. Young Drivers' Preferences for In-Vehicle Systems and Interaction Modality

3.1.1. Preferences for In-Vehicle Systems

A series of *t*-tests were performed to determine whether significant differences existed between young Chinese and German drivers regarding the importance ratings of 10 IVIS functions and eight ADAS functions. The statistical results are summarized in Table 3. In terms of IVIS functions, young Chinese drivers gave significantly higher scores than German drivers except for radio and navigation. Specifically, Chinese drivers rated four functions over 4.00 and the mean values for the other functions were within the scope of 3.46–3.96. German drivers perceived these functions to be less important than Chinese drivers and four systems were rated below 3.50. However, young German drivers perceived radio and navigation to be more important. Moreover, navigation and AC were the most preferred functions for both groups and weather was the least valued function.

Table 3. Means (standard deviations) and t values for Chinese and German drivers on the in-vehicle systems.

IVS	Chinese (n = 232)	German (n = 94)	t-Value
	Mean (sd)		
IVIS functions			
Radio	3.61 (1.05)	3.85 (1.09)	−1.85
Media	3.95 (0.91)	3.38 (1.17)	4.22 ***
Telephone	3.84 (0.96)	3.46 (1.12)	2.90 **
Navigation	4.19 (1.09)	4.44 (0.97)	−1.95
Parking	4.15 (0.97)	3.61 (1.24)	3.76 ***
Bluetooth	3.96 (0.94)	3.61 (1.24)	2.53 *
AC	4.79 (0.47)	4.37 (0.96)	4.06 ***
Weather	3.46 (1.06)	2.65 (1.17)	6.06 ***
Driving mode	3.83 (0.97)	2.96 (1.17)	6.88 ***
Settings	4.07 (.084)	3.31 (1.11)	5.95 ***
ADAS functions			
RV	4.51 (0.73)	3.53 (1.09)	8.01 ***
ACC	3.72 (0.98)	3.40 (1.07)	2.50 *
LDW	3.81 (0.94)	3.38 (1.10)	3.31 **
AEB	4.42 (0.77)	4.26 (0.89)	1.55
LCA	3.89 (0.92)	3.09 (1.16)	6.05 ***
FCW	4.27 (0.87)	4.02 (0.93)	2.31 *
NVS	4.11 (0.98)	3.53 (1.21)	4.14 ***
TPMS	4.40 (0.76)	3.41 (1.19)	7.50 ***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

In regards to ADAS functions, the Chinese sample of young drivers perceived all these functions to be more significantly important compared to German drivers except for AEB. The German sample gave high scores to AEB and FCW, while the mean ratings of the other systems were between 3.09–3.53. However, except for ACC, LDW and LCA, Chinese drivers rated ADAS functions above 4.00.

3.1.2. Preferences for Interaction Modality

As indicated in Figure 1, the rotary with a display screen was the most preferred interaction modality for both Chinese (60.2%) and German drivers (51.1%). Touch screen was the second favorable mode for the Chinese sample (19.9%), while German drivers rated knobs second (19.1%), which was, however, the least favorite one for Chinese drivers (9.1%). Additionally, a rather small proportion of participants from the two groups (10.8% Chinese, 13.8% German) showed interests in voice control.

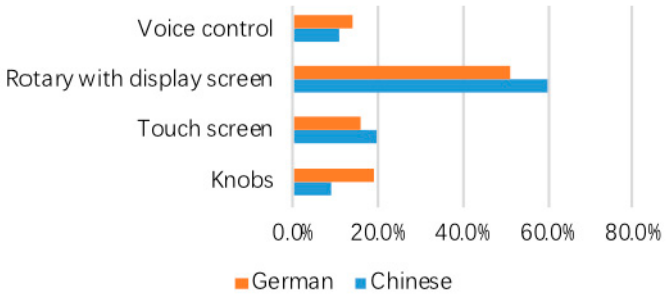

Figure 1. Participants' options for interaction modality.

3.2. Behavioral Effects Caused by Secondary Tasks

3.2.1. Critical Scenarios

In this subsection, driver behavior was investigated first by inquiring the frequency of engaging in a critical situation when drivers were performing a secondary task. In general, young Chinese drivers were more frequently engaged in these eight scenarios compared to young German drivers. As shown in Figure 2, the sum of the three proportions (very often, often and sometimes) for Chinese drivers in each scenario was higher than that of the German counterpart. The biggest disparity appeared in S3; 37.5% of Chinese participants reported that they sometimes hit/nearly hit pedestrians/bicyclists and 7.3% came across this situation often. However, the total proportion of German drivers who encountered this situation often and sometimes was less than 10% (4.3% seldom, 5.4% often). The most dangerous behavior, running/nearly running red lights (S4), was reported to happen more frequently to young Chinese drivers. They indicated to be involved 31.9% of them sometimes and 10.8% often in this violation when dealing with a secondary task-much higher than German participants were. Moreover, the Chinese sample of young drivers was more likely to be unaware of the cutting-in vehicles in front (S2) with 40.9% of participants sometimes having to brake abruptly to avoid a collision (10.0% of these drivers often faced such hazards). Though young German drivers were experiencing this scenario less frequently, they were very likely to fail to notice the sudden braking of the leading car (S1). This performance was comparable to that of young Chinese drivers.

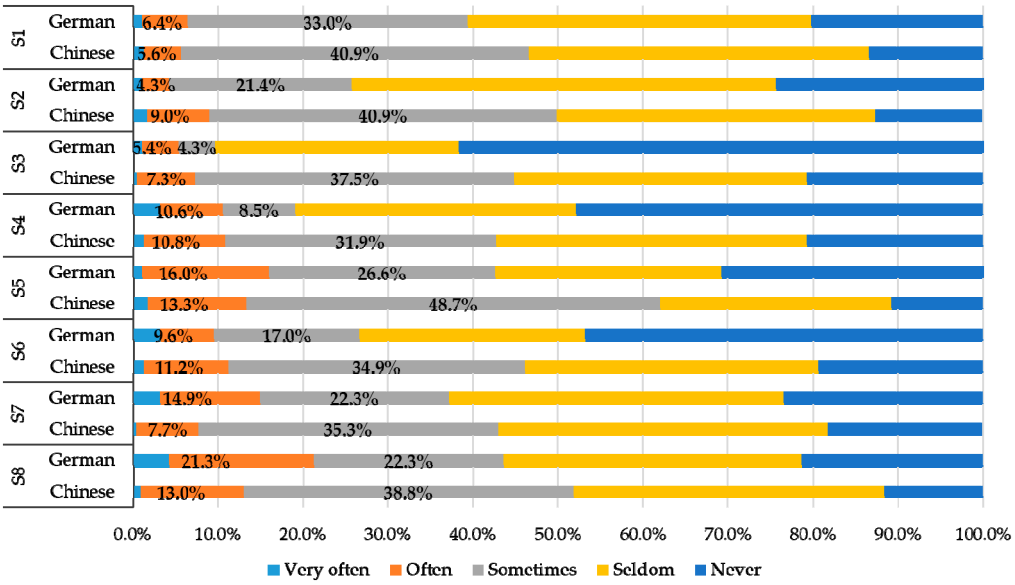

Figure 2. Cultural comparison of frequency of involvement in critical scenarios.

Overall, when conducting a secondary task, young German drivers were much more careful about the potential hazards than the Chinese counterpart. In spite of their prudence, German drivers were still often inclined to encounter some scenarios, which decreased traffic efficiency. For example, they often (21.3%) misinterpreted/overlooked traffic signs (S8) and often (16.0%) got honked at after the traffic lights turned green (S5). In addition, deviating from the current lane (S7) often (14.9%) happened to them. However, the performances of young Chinese drivers in these situations were comparable. 62.0% of the participants sometimes or often engaged in a task for so long at the intersection that the traffic behind could get impatient. Additionally, manipulating in-vehicle functions could make Chinese drivers enter the wrong lanes more frequently when approaching intersections.

3.2.2. Secondary Tasks

Six of the most common secondary tasks, which may influence driver behavior and distract them from safe driving were presented, i.e., looking up navigation, dialing the phone, playing music, looking up for information, connecting Bluetooth and setting up AC.

Of the 232 young Chinese drivers, 10 (4.3%) picked none of the six tasks, however, they reported other distractions such as smoking, eating or looking in the rear view mirror when encountering a hazardous scenario. Similarly, the six tasks were not selected by two of 94 German young drivers. Moreover, day-dreaming was considered a factor impacting driver behavior.

The other participants selected one or more tasks as can be seen in Figure 3. When involved in a hazardous situation, 56.8% young Chinese drivers and 66.3% young German drivers reported that they were looking up the navigation, which seemed to be the most harmful secondary task. For Chinese drivers, making phone calls was the second most frequent action that caused danger, which was, however, a less frequent task for German drivers. Instead, 44.6% of Germans were playing music when facing a critical scenario. Connecting Bluetooth was the least cause of danger for the Chinese sample, while it was setting up air conditioning for the German sample. As shown in Figure 3, most drivers (60.3% Chinese and 70.6% German) dealt with more than one secondary task when driving and any of these behaviors were very likely to cause danger.

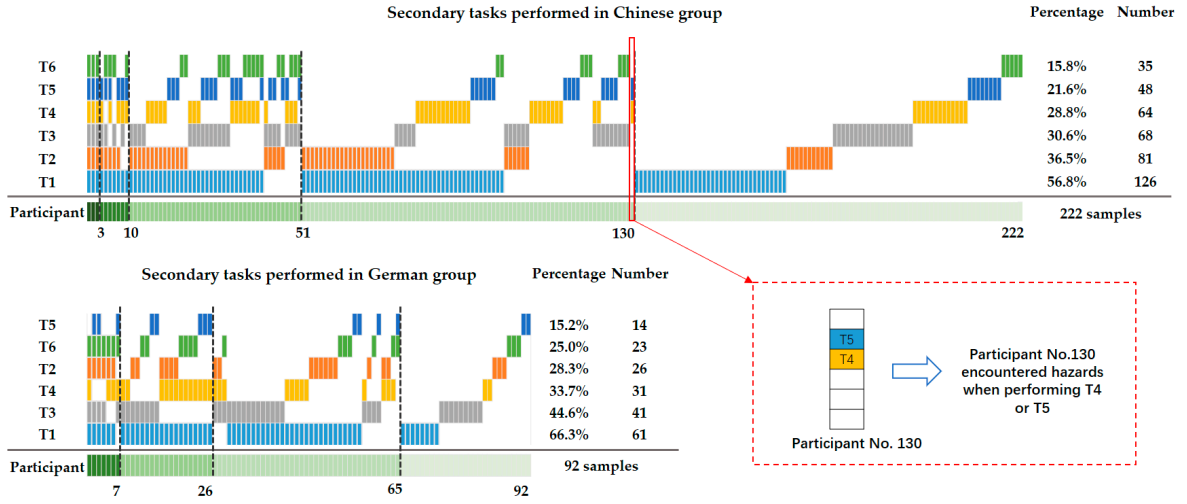

Figure 3. The secondary tasks performed by Chinese and German participants when encountering hazardous situations. Each column represented one participant and every cell represented one task. The green gradient at the bottom represented the overall participants, as the color went from deep to shallow, the number of performed tasks decreased. T1 = looking up navigation, T2 = dialing phone, T3 = playing music, T4 = looking up for information, T5 = setting up AC, T6 = connecting Bluetooth.

3.2.3. Relationship between Secondary Tasks and Driver Behavior

To determine the relationship between secondary tasks and driver behavior, a series of ordinal logistic regression analyses were conducted and an odds-ratio was applied in which 1 standard deviation means a unit change in predictor variables as shown in Table 4. Firstly, a series of parallel lines tests were examined where the significance levels were above 0.05, which represented the non-violation of odds assumption. In terms of Chinese drivers, looking up at navigation was significantly related to the involvement in critical scenarios (S1, S2, S4, S5 and S8); dialing the phone was related to S4 and S8 and connecting Bluetooth was related to S1 and S2. However, playing music, looking up for information and setting up AC were not significantly correlative to the engagement in hazards. With respect to the German sample of young drivers, playing music was significantly related to the scenario of entering wrong lanes when approaching intersections, looking up for information was related to the scenario of being honked at by other vehicles when traffic lights turn green. While looking up at

the navigation, dialing the phone and setting up AC were not significantly correlative to hazardous situations involvement.

Table 4. Ordinal Logistic Regression models predicting critical situations involvement regarding secondary tasks, S1–8 = scenario 1–8, T1 = looking up navigation, T2 = dialing phone, T3 = playing music, T4 = looking up for information, T5 = setting up AC, T6 = connecting Bluetooth, CN = Chinese, DE = German.

	Odds Ratio (95% Confidence Interval)											
	T1		**T2**		**T3**		**T4**		**T5**		**T6**	
	CN	**DE**	**CN**	**DE**	**CN**	**DE**	**CN**	**DE**	**CN**	**DE**	**CN**	**DE**
S1	**1.69** * (1.04, 2.74)	1.42 (0.65, 3.10)	0.91 (0.55, 1.51)	2.12 (0.91, 4.94)	1.21 (0.72, 2.06)	0.98 (0.46, 2.08)	1.05 (0.61, 1.79)	0.74 (0.33, 1.62)	0.87 (0.48, 1.58)	0.59 (0.21, 1.70)	**2.30** * (1.15, 4.60)	0.80 (0.34, 1.89)
S2	**1.73** * (1.07, 2.80)	1.12 (0.50, 2.48)	1.58 (0.96, 2.62)	1.52 (0.65, 3.57)	1.24 (0.73, 2.09)	1.09 (0.51, 2.34)	1.30 (0.76, 2.23)	1.06 (0.47, 2.38)	1.10 (0.61, 1.98)	1.44 (0.50, 4.18)	**2.00** * (1.02, 3.95)	0.84 (0.35, 2.04)
S3	1.21 (0.76, 1.95)	0.73 (0.32, 1.70)	1.53 (0.93, 2.51)	0.80 (0.32, 2.03)	1.61 (0.96, 2.72)	1.53 (0.68, 3.48)	1.11 (0.66, 1.88)	1.22 (0.52, 2.88)	1.19 (0.66, 2.13)	1.54 (0.51, 4.64)	1.25 (0.65, 2.42)	0.86 (0.33, 2.25)
S4	**1.74** * (1.08, 2.80)	0.89 (0.40, 1.96)	**1.98** ** (1.20, 3.25)	1.01 (0.43, 2.35)	1.03 (0.62, 1.72)	1.23 (0.58, 2.65)	0.98 (0.58, 1.65)	2.04 (1.09, 3.19)	1.16 (0.65, 2.06)	1.29 (0.45, 3.71)	0.84 (0.45, 1.62)	0.49 (0.19, 1.25)
S5	**2.04** ** (1.25, 3.34)	1.28 (0.60, 2.75)	1.20 (0.73, 2.00)	1.50 (0.66, 3.38)	1.12 (0.66, 1.89)	0.96 (0.46, 1.99)	1.23 (0.72, 2.11)	**3.02** ** (1.36, 6.71)	1.09 (0.60, 1.98)	1.15 (0.41, 3.18)	1.90 (0.96, 3.76)	1.19 (0.51, 2.76)
S6	1.47 (0.92, 2.37)	1.22 (0.55, 2.68)	1.62 (0.99, 2.66)	0.64 (0.27, 1.51)	1.03 (0.62, 1.72)	**2.32*** (1.07, 5.00)	1.25 (0.74, 2.11)	0.92 (0.41, 2.04)	1.37 (0.77, 2.44)	0.97 (0.34, 2.79)	1.48 (0.77, 2.85)	1.09 (0.45, 1.89)
S7	0.95 (0.60, 1.54)	1.03 (0.48, 2.21)	1.46 (0.89, 2.41)	1.23 (0.54, 2.76)	1.62 (0.96, 2.74)	0.75 (0.36, 1.57)	0.82 (0.48, 1.39)	1.42 (0.65, 3.10)	1.19 (0.66, 2.13)	2.11 (0.75, 5.91)	1.33 (0.69, 2.59)	0.67 (0.25, 1.53)
S8	**1.72** * (1.06, 2.77)	1.46 (0.68, 3.13)	**1.84** * (1.11, 3.04)	1.08 (0.48, 2.44)	1.09 (0.65, 1.83)	1.76 (0.84, 3.69)	1.02 (0.60, 1.73)	1.58 (0.73, 3.42)	1.56 (0.87, 1.11)	1.74 (0.63, 4.84)	1.30 (0.67, 2.52)	0.70 (0.30, 1.63)

* $p < 0.05$, ** $p < 0.01$.

4. Discussion and Conclusion

4.1. Young Drivers' Preferences for In-Vehicle Systems and Interaction Modality

The aim of the first part was to investigate whether significant differences existed in the samples of young drivers (i.e., Chinese and German) regarding their preferences for IVS functions. Young Chinese drivers perceived most of the selected IVS functions to be significantly more important than German drivers did and the only exceptions were radio, navigation and AEB. The partiality of young German drivers for radio and navigation was reflected in the high ratings and also has been indicated in other studies [28]. To the contrary, young drivers of the Chinese sample showed more interests in media than radio. Many auto manufactures have merged the radio into the media area of the center stack, saving space for other functions. Our findings revealed that young Chinese drivers accentuated the importance of parking information. This is possibly due to the discrepancy between the enormous amount of vehicles and scarcity of parking space in China. Many navigation apps in cell phones e.g., Baidu map or Amap already provide parking information. These apps could offer several parking

places when drivers are approaching destinations. However, it is hard for drivers to know which one of the recommended parking lots is the most convenient to reach the destination, how much it will charge and how many places are left; processing this information is a highly demanding task and extremely dangerous while still driving. Moreover, when parking on the roadside or in parking lots, drivers have to engage in a mixed traffic environment with bicyclists and other non-motorized vehicles, resulting in an overloaded road environment for drivers. If drivers are traveling a familiar route, there might be no need to navigate but information regarding parking is still required. Therefore, it would be better to extract parking information from the navigation and make it an independent function for young Chinese drivers. However, parking information was not quite as valued by young German drivers, likely because there is sufficient parking space or other alternatives in Germany.

With respect to the ADAS functions, young Chinese drivers considered the functions significantly important. In fact, longitudinal assistance, in particular, AEB and FCW were the most valued systems by both groups, which implies that longitudinal hazards are perceived more critical and drivers need more assistance systems to be warned about dangerous situations. Nevertheless, ACC was not quite as favored by young Chinese drivers and was rated the least, which probably is due to the complex traffic environment in China incapacitating a proper functioning of ACC. These findings are consistent with previous research [27]. Additionally, young German drivers also perceived ACC less important. The most suitable situation to use ACC may be on the freeway, yet young German drivers may prefer to drive by themselves with a desirable speed because there is no speed limit on some freeways. To set a speed seems inefficient and boring for young German drivers. In addition, differences in lateral assistance between the two groups were significant, yet both samples considered these functions as less important compared to other functions. However, young Chinese drivers still gave high scores, which indicates that they still believe the lateral assistance useful to some extent.

In terms of interaction modality, the rotary with display screen was the most favorable mode for both Chinese and young German drivers. Several popular German-brand cars adopt this design such as iDrive of BMW, COMAND of Mercedes and MMI of Audi, which makes it rather understandable why 51.1% of young German drivers chose this modality. Interestingly, an even higher proportion (60.2%) of the Chinese sample preferred this indirect interaction, which could provide a tactile feedback enabling drivers to confirm the correctness of their input [1]. According to the statistics of the China Association of Automobile Manufacturers (CAAM), German-brand cars remained the most sold of foreign cars in China since 2012 and reached over 4.8 million shipments in 2017, which makes Chinese drivers become familiar with this modality. The touchscreen was the second preferred modality for young Chinese drivers, however, manual input is prone to errors unless the screen is big enough like the design of Tesla [38]. This was why only a fraction of young Chinese drivers (19.9%) chose this mode. It is interesting that around 20% German drivers preferred knobs as the interaction modality, which may imply that German drivers perceive the tactile feedback quite significantly.

4.2. Relations between Secondary Tasks and Driver Behavior

The second section attempts to clarify the relations between secondary tasks and driver behavior. Of the eight critical scenarios depicted in this study, five were safety-related (S1, S2, S3, S4 and S7) and the other ones were efficiency-related. Concerning the degradation of driving performances, results revealed that young drivers of the Chinese sample were more likely to encounter safety-related scenarios, especially when confronted with pedestrians or bicyclists. Less than 10% of young German drivers sometimes or often encountered vulnerable road users in risky situations, while the proportion for Chinese sample reached 44.8%. These remarkable differences can be explained by the distinct road traffic conditions between the two countries. In China, the heavy mixed traffic poses a vital threat to road safety, with the lacking separation between vehicles and bicyclists resulting in more conflicts. Moreover, the relationship between drivers and pedestrians seems to be intense, jaywalkers seriously interfere with safe driving, but drivers appear to be unwilling to yield for pedestrians either at an un-signalized zebra or in right turn traffic. While the situation is totally different in

Germany, and German drivers usually stop meters away from the sidewalk when seeing pedestrians intending to cross. As indicated in Figure 2, sudden braking due to the lack of attention to cutting-in vehicles and running red lights were also hazardous behaviors that young Chinese drivers frequently committed. Active lane-changing in China is a serious issue especially during peak times, which leads to frequent conflicts with the cutting-in vehicles. However, deviating from the current lane was reported to happen more often to young German drivers instead of Chinese counterpart. Regarding the efficiency-related scenarios, young German drivers were influenced severely by secondary tasks as reflected in the high proportion of drivers who often were involved in S5 (honked by other vehicles after the traffic lights turn green) and S8 (Misinterpreting/overlooking traffic signs). Overall, manipulating in-vehicle functions while waiting for the traffic lights was the most frequent behavior for both groups. In conclusion, German drivers behave more safely than Chinese ones do when performing a secondary task. This is likely to be due to German drivers' respect of traffic regulations. Yet, driving efficiency is still influenced when drivers' attention diverted.

The 6 secondary tasks presented in this study are the most popular and common ones with different operational complexity. With respect to navigation, it is the most important secondary task and requires a combination of diverse driver resources, for example, visual resource, auditory resource (speech instructions), manual resource (destination input or route-switch) and cognitive resource (analysis of road environment and navigation information) [34]. Thus it seems evident why young drivers of both groups considered looking up navigation to be the biggest distraction that put them in hazardous situations. Similarly, drivers could easily involve in danger if their cognitive resource is occupied too much such as making phone calls [12,13], therefore young Chinese drivers regarded it to be the second most factor of danger. Playing music was, however, reported to be one of the most common actions conducted when encountering a hazardous scenario for both groups. Looking up for information was rated similar to looking up navigation, yet it is not as important and necessary as navigation which makes it not a common behavior. As for setting up AC, it seems more like an issue of operational familiarity and after a couple of times drivers could even manipulate it without taking their eyes off the road [34]. Connecting Bluetooth is somehow a complicated task because drivers have to take several steps on their phones to match the function for the first time, yet it would be automatically connected next time which causes less distraction.

The first hypothesis is confirmed: secondary tasks impose negative impacts on driver behavior. For young Chinese drivers, looking up navigation, dialing phone and connecting Bluetooth are three most dangerous tasks that impact driver safety severely, such as conflicts with sudden braking and cutting-in vehicles, and traffic lights violations. It is understandable that navigation, which requires many driver resources, is the biggest distraction relating to behavioral degradation. Despite connecting Bluetooth is the least frequent task for young Chinese drivers, this task is not simply that drivers have to turn on the Bluetooth on the phone, then go through the sub-menu on the interface to choose the correct matching unit, and wait until it is linked. Moreover, the heavy cognitive load (dialing phone) also badly impairs drivers' perception of road traffic, e.g., they may see traffic lights turning red, yet still fail to respond in time or appropriately. In general, there are little relations between secondary tasks and behavior impairment for young German drivers, though they reported that they were performing secondary tasks when engaging in dangerous situations. This could be because young German drivers conduct secondary tasks less frequently than reported, or they may be more vigilant and careful about the road environment when performing secondary tasks. Overall, it seems that secondary tasks impose little influence on the behavior of German drivers compared to young Chinese drivers, which implies remarkable cultural differences.

As more and more attention is dedicated to cell phone use while driving, many studies have been dedicated to determining the negative effects of phone-related tasks. However, navigation seems to be omitted which still troubles young Chinese drivers profoundly. It is generally recognized that navigation should be an assistance function to promote traffic efficiency, thus sometimes driver behavior impairment out of navigation is unconsciously ignored. Due to the massive and complex

road environment in China, any secondary task increases the operational difficulty for Chinese drivers. When drivers have to constantly look away from the road to check the map, they could easily find themselves in hazardous situations, especially due to lack of attention to the cutting-in vehicles which often cut aggressively and abruptly. From this perspective, the importance of longitudinal assistance systems, particularly AEB and FCW, is rather obvious. In summary, navigation is the most valued IVIS function for young Chinese drivers, and the most frequent task they engage in when encountering safety-related and efficiency-related scenarios. AEB and FCW are vital functions for Chinese drivers.

Future studies should address whether the efficiency improvement can compensate the behavior degradation caused by navigation systems and investigate appropriate warning distances of AEB and FCW in Chinese traffic.

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