Effect Factors Analysis of Driver's Freeway Route Deviation Based on Questionnaire Survey Data

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Abstract. In order to investigate the effect factors of route deviation when drives use navigation application on freeways, we conducted a route deviation questionnaire on 219 drivers. The driver cognitive patterns were summarized from the questionnaire by exploratory factor analysis, and effective explanatory variables were screened by chi-square test. Meanwhile, related social factors were screened by chi-square test and Tukey's Honestly Significant Difference (HSD) test. Finally, a binary logistic regression model was established to reveal the influence weight of related factors on deviation from the route. The results show that navigation application design, navigation usage habits, traffic environment and education can influence drivers' use of navigation, with navigation application design having the greatest degree of influence, followed by navigation usage habits, and then traffic environment interference and education. Specifically, navigation application that is consistent with most drivers' habits can reduce the probability of route deviation; those with good driving habits have less route deviation; complex traffic environments can increase the probability of route deviation; the probability of route deviation decreases as education increases. The research contributes to the optimization of freeway navigation application.

Keywords: Route deviation · Freeway · Navigation language optimization · Logistic regression

1 Introduction

In recent years, navigation map application has developed rapidly as an essential tool for travel planning and route navigation. Although the overall performance of navigation maps tends to improve the efficiency of drivers' travel in unfamiliar environments and solve congested sections [1, 2], the partial inability of existing navigation systems still has optimization potential. Even, some studies found that it has some negative effects on driving behavior, for example, Tamer et al. concluded that it can distract drivers with the help of navigation systems, which may lead to an increase in road accidents, and investigated that navigation system display size, ambient lighting, and gender can affect

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driving safety [3, 4]; Kaber analyzed that when the driver's vision and cognition are occupied by navigation information, it will increase the response time and the number of operation errors [5]; Jamson et al. found that both visual and auditory navigation tasks delayed the driver's response to unexpected conditions [6]. Thus, navigation still has optimization potential, e.g., Zhao identified the effect of variable message signs on individual path selection behavior by studying the different effects on different groups [7]; Lee explored the best strategy for delivering navigation information to drivers by controlling the type and mode of information [8]; Larsson proposes pro-social control strategies for vehicles that take into account driving comfort and traffic efficiency [9]; Li propose a heuristic routing algorithm to identify the feasible routing paths for shared rides that interest both ridesharing drivers and riders [10]. Shi explored factors related to autonomous driving safety [11].

In terms of the navigation voice prompt method, Uang et al. noted that the choice of command or descriptive voice announcements depending on the content of the information was beneficial in improving driver compliance with prompts [12]; Large et al. showed that high trust speech increased driver trust in navigation but did not significantly affect driver attention to wayfinding signs [13]; Lavie et al. found that drivers performed best when using the least informative map [14]. The above studies reveal the effects of navigation information giving methods on driving behavior and subjective cognition, and point the way for further optimization of navigation information giving methods. In terms of speech wording, Dalton et al. found that simple voice commands were easier to follow and less intrusive to drivers than complex voice commands [15]; Rasker et al. suggested that navigation voice prompts don't need to provide road names because it is not easily and quickly understood by the driver [16]. Visually, Lin et al. found no significant difference in driving performance between 2D and 3D map, while sweeping behavior was more frequent in 3D than 2D, and drivers made significantly fewer navigation errors when using the sub-window navigation display [17].

As for drivers, Yang explored the factors that influence drivers' willingness to use mobile navigation applications and found that the influencing factors are attitude, perceived usefulness, driver orientation, navigation application affinity, and perception of distraction [18]. Meanwhile, Bian's study found that an interaction between prompt timing and prompt message of the voice navigation system affect the driver's psychological state and vehicle operation on urban highways [19]; Ali and Fu did some research on lane change conditions separately [20, 21]; Imants believes that a deeper understanding of how drivers use multiple sources of traffic information can help improve driver safety and comfort, increase the availability of information sources, and help reduce driver stress, anxiety and information overload while driving [22]. Pan explored the relationship between speed behavior of participants and driving styles [23]. In addition, Emmerson has found that the use of in-car navigation systems provides better road information for older drivers, and that further improvements in navigation design are needed to improve the quality of service for older drivers [24].

From the above research, it is clear that there is still potential for optimizing navigational speech. In this paper, the influencing factors of route deviation will be studied and analyzed from the driver's cognitive pattern, hoping to explore the navigation language that is more in line with the driver's cognitive habits, make the electronic navigation system better assist the driver on the freeway.

2 Research Content

2.1 Questionnaire Design

Combined with the existing questionnaires [18], the questionnaire of this study is designed based on the problems of voice prompts in navigation application and the actual situation of drivers using navigation application, in order to investigate the factors influencing drivers' deviation from the route when using navigation on freeways. The questionnaire consists of two parts: the first part is a non-scale questionnaire, which collects basic information about the respondents, such as gender, age and whether they often deviate from the route when using navigation on freeway; the second part is a scale questionnaire, with 17 questions related to the use and design of navigation (Table 1). The scale questions were scored on a 5-point Likert scale: 1 - strongly disagree, 2 - disagree, 3 - barely agree, 4 - relatively agree, 5 - strongly agree.

Table 1. Question content

Question	Content
Q6	Trust the navigation can provide useful information
Q7	When you go off course, it's mostly a navigation issue
Q8	Voice prompt is too quick to think and judge accordingly
Q9	Voice prompt is too late, resulting in delayed response
Q10	Voice prompt is too early and are disruptive to current driving
Q11	The default voice is too monotonous to focus on the prompt
Q12	Insufficient voice prompt times result in poor prompt effect
Q13	More focus on navigation voice than screen
Q14	I will take action immediately when hearing the prompt
Q15	I slow down and notice the traffic conditions when hearing the prompt
Q16	Focus on navigation information such as routes, turns, and distances
Q17	Focus on location information such as maps, locations, and driveways
Q18	Focus on violation information such as speed limit
Q19	Focus on road conditions information such as traffic congestion,
Q20	There are more traffic around, which affects my operation
Q21	The prompt doesn't match the road markings
Q22	The prompt doesn't match the actual road

2.2 Respondents

The survey was focused on drivers in the age of 20 to 64 given that drivers aged 18–20 are still in their driving practice period and have little experience in freeway driving, as well as the minority of drivers over 65 who use mobile phones while driving. This questionnaire was distributed in April 2021. To ensure that the surveyed drivers fill in the questionnaire as honestly as possible, a statement is made at the beginning of the questionnaire to inform the respondents of the purpose and meaning of this questionnaire. In the end, 231 questionnaires were returned with 12 questionnaires with missing information, 219 questionnaires were valid, with an efficiency rate of 94.8%.

The basic information statistics of the survey objects are shown in Table 2. Among them, 107 were males and 112 were females with similar percentages. The age was divided into segments by every 15 years, with 40.18% of the survey objects aged 20–34, 40.64% aged 35–49 and 19.18% aged 50–64. The percentage of driving experience less than 3 years was 29.22% (including 11.41% less than 1 year; 17.81% 1–3 years) and greater than 3 years was 70.78%. Education was divided according to junior high school and below, high school, bachelor and postgraduate, accounting for 12.79%, 36.53%, 42.92%, and 7.76%, respectively.

Table 2. Information of participants

Information	Categories	Number	Proportion
Gender	Male	107	48.86%
	Female	112	51.14%
Age	20–34	88	40.18%
	35–49	89	40.64%
	50–64	42	19.18%
Driving experience	Less than 1 year	25	11.41%
	1–3 years	39	17.81%
	More than 3 years	155	70.78%
Education	Junior high and below	28	12.79%
	High school	80	36.53%
	Bachelor	94	42.92%
	Postgraduate	17	7.76%

3 Effect Factors of Route Deviation

3.1 Exploratory Factor Analysis (EFA)

An exploratory factor analysis was conducted on the 17 questions that reflect the use of navigation application, to determine the corresponding factor structure. The KMO test and Bartlett's spherical test were conducted on the questionnaire data: the KMO measure was 0.857, indicating that the sample size was suitable for factor analysis; the Bartlett's spherical test result was 2002.298 (the significance level $P = 0.000 < 0.001$), indicating the possibility of common factors among the observed variables. Then, the results of the Scree Test are shown in Fig. 1, the first 3 triangles are above the bend of the curve, indicating that there are 3 factors with eigenvalues greater than 1, so the questionnaire data are suitable for extracting 3 common factors.

The factor structure and its loadings are shown in Table 3: Factor 1, named as navigation application design, contains 7 questions, mainly reflecting the driver's feelings about navigation and the reasonableness of navigation voice settings, with a variance contribution rate of 26.476%; Factor 2, navigation usage habits, contains 7 questions, mainly reflecting the driver's behavioral habits and concerns about navigation information, with a variance contribution rate of 25.631%; Factor 3 is traffic environment interference, containing 3 questions, reflecting the influence of traffic environment on navigation use, with a variance contribution rate of 13.815%, and a cumulative variance contribution rate of 65.922% for the 3 common factors.

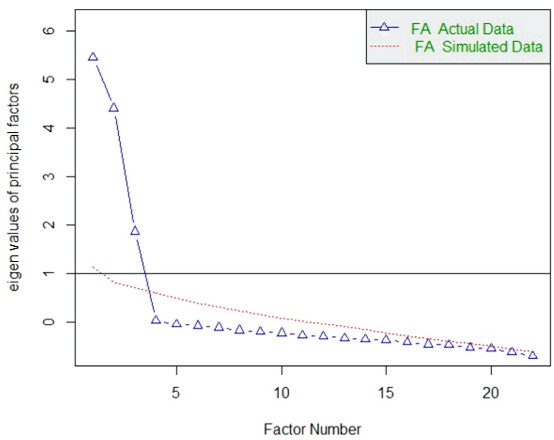

Fig. 1. Parallel analysis scree plots

Table 3. The factor loading matrix

Question	Navigation design	Usage habits	Traffic environment
Q6	0.733		
Q7	0.813		
Q8	0.805		
Q9	0.779		

(*continued*)

Table 3. (*continued*)

Question	Navigation design	Usage habits	Traffic environment
Q10	0.774		
Q11	0.757		
Q12	0.812		
Q13		0.761	
Q14		0.808	
Q15		0.795	
Q16		0.793	
Q17		0.811	
Q18		0.849	
Q19		0.778	
Q20			0.853
Q21			0.875
Q22			0.870

3.2 Questionnaire Reliability and Validity Tests

Cronbach's alpha reliability coefficient method was used to test the internal and overall reliability of the questionnaire. The test results showed that the alpha coefficient of navigation application design, navigation usage habits, traffic environment interference and the overall questionnaire were 0.896, 0.906, 0.845, and 0.841, which were higher than 0.80, indicating that the internal and overall questionnaire had good reliability. Meanwhile, the cumulative variance contribution of the three public factors according to the exploratory factor analysis was 65.922%, which is higher than 60%, indicating that the questionnaire has good structural validity.

4 The Effect of Driver Cognitive Models on Route Deviation

One-way ANOVA was used to analyze the differences in driver cognitive patterns and whether route deviations occurred frequently, and the results are shown in Table 4. Navigation application design, navigation usage habits, and traffic environment interference were significantly different in whether or not to deviate ($P < 0.01$). The 219 samples were divided into two small samples based on whether they deviated from the route (153 for the frequently deviated sample and 66 for the infrequent deviated sample). The mean and variance of each question score were respectively calculated for the two samples, while the chi-square test was used to further determine whether there was a significant difference between each question, and the results are shown in Table 5.

It is apparent that the frequently deviated group score higher than the infrequently deviated group on each question, and the scores are distributed around 4 (relatively agree), indicating that drivers who use navigation and frequently deviate are more dependent on the navigation application, while their driving behavior is more influenced by navigation. In the results of the chi-square test, each question of the 3 factors has a significant difference for frequent route deviation, with the navigation application design factor has a more significant difference for frequent route deviation. Therefore, for improving the driver's behavior of route deviation when using navigation application on the freeway, we should first consider the navigation application's own design.

Table 4. Analysis of variance

Variable	Navigation design		Usage habits		Traffic environment	
	F-value	Saliency	F-value	Saliency	F-value	Saliency
Route deviation	61.534	0.000**	19.472	0.000**	22.562	0.000**

Note: ** indicates $P < 0.01$; * indicates $P < 0.05$

Table 5. Chi-square test

Question		Mean (Standard deviation)		Results
		Frequently deviate	Infrequently deviate	
Factor 1:	Q6	4.16(0.97)	3.20(1.40)	0.000
	Q7	4.03(1.06)	3.12(1.23)	0.000
	Q8	3.96(1.09)	2.89(1.22)	0.000
	Q9	4.07(1.00)	2.91(1.29)	0.000
	Q10	4.01(1.05)	2.79(1.29)	0.000
	Q11	4.08(1.00)	3.23(1.30)	0.000
	Q12	4.06(1.04)	2.95(1.30)	0.000
Factor 2:	Q13	3.91(1.18)	3.14(1.16)	0.000
	Q14	3.97(1.04)	3.27(1.25)	0.000
	Q15	4.05(1.10)	3.33(1.35)	0.002
	Q16	3.99(1.06)	3.32(1.39)	0.003
	Q17	3.94(1.14)	3.52(1.19)	0.008
	Q18	3.86(1.12)	3.30(1.24)	0.001
	Q19	3.94(1.06)	3.21(1.26)	0.000
Factor 3:	Q20	4.11(1.03)	3.48(1.04)	0.000
	Q21	3.99(1.04)	3.03(1.12)	0.000
	Q22	4.08(0.96)	3.33(1.26)	0.000

5 The Effect of Demographic Factors on Route Deviation

Gender, age, driving age and education were subjected to a chi-square test to explore the effect on route deviation, and the results are shown in Table 6. Education was associated with whether route deviation occurred frequently ($P = 0.000 < 0.01$). The participants with high school degrees accounted for 45% of frequent route deviations; a bachelor's degree accounted for 64% of infrequent route deviations. To further investigate differences in education levels, a multiple comparison analysis of the two was conducted using the Tukey's HSD test, and the results are shown in Fig. 2. There is a significant difference between education below high school and education above the bachelor level at the confidence interval 95% level, indicating that the higher the education level, the less frequent route deviation occurs when using navigation application, which confirms that the level of education is a factor in driving accidents. Based on the above tests, high school can be used as a cut-off to redefine the classification and values of the education variable: 1 - high school and below, 2 - bachelor's degree or higher.

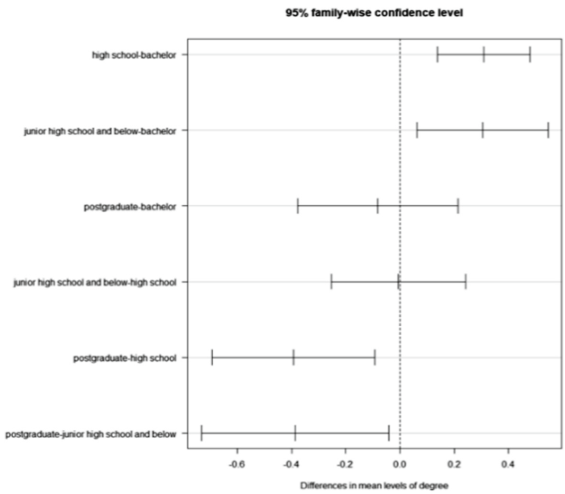

Fig. 2. Multiple comparison of means-Tukey HSD

6 Response to Effect Factors of Route Deviation

To understand the extent of which navigation application design, navigation usage habits, traffic environment interference, and educational attainment could affect deviation, a binary logistic regression model is established to make predictions. Whether a driver frequently occurs route deviation is a dichotomous quantity, where 0 indicates infrequent or no deviation and 1 indicates frequent deviation. The model uses whether route deviation occurs frequently as the dependent variable, and uses the three factors and the education variable as the independent variables, to establish a model for freeway route deviation. The results obtained are shown in Table 7. The significance level of each variable is less than 0.01 and can be used to predict the likelihood of route deviation. The Hosmer-Lemeshow test value for the overall model was 2.318 ($P = 0.970 > 0.05$), indicating that the model fits well and the prediction accuracy is 85.40%. Therefore, the four factors can be used as inputs to the route deviation prediction model.

According to the regression coefficients of the independent variables, the design of the navigation application has the greatest influence on deviate from the route. Specifically, the more the design of the navigation voice and display screen conforms to the cognitive habits of most drivers, the less deviations from the route occur. The second is the driver's habit of using navigation. Those who have good driving habits can get information from the navigation tips that are beneficial to them to reduce the deviation from the route. Furthermore, the traffic environment can reduce the effectiveness of navigation prompts and increase the probability of route deviation. Finally, the higher the driver's education, the lower the probability of route deviation. The model is useful for predicting route deviation when drivers use navigation application on the freeway, improving navigation prompts and reducing the probability of route deviation.

Table 6. Chi-square test for demographic factors

Information	Categories	Proportion		Results
		Frequently deviate	Infrequently deviate	
Gender	Male	46%	55%	0.269
	Female	54%	45%	
Age	20–34	36%	50%	0.127
	35–49	44%	32%	
	50–64	20%	18%	
Driving experience	Less than 1 year	10%	15%	0.518
	1–3 years	18%	17%	
	More than 3 years	72%	68%	
Education	Junior high and below	16%	6%	0.000**
	High school	45%	17%	
	Bachelor	34%	64%	
	Postgraduate	5%	13%	

Table 7. Logistics regression analysis results

Independent variable	B	Wald	Sig	Exp(B)
Education	−2.170	20.038	0.000**	0.114
Navigation application design	1.695	39.809	0.000**	5.449
Navigation usage habits	1.328	27.759	0.000**	3.775
Transportation environment	1.106	20.932	0.000**	3.021
Constant	5.114	31.802	0.000**	166.368

Note: ** indicates $P < 0.01$; * indicates $P < 0.05$

7 Conclusion

In this paper, a questionnaire was used to analyze the use of navigation applications by 219 drivers, and the concept of the cognitive model was introduced to illustrate the factors influencing the occurrence of route deviation when drivers use navigation. In general, navigation application that meets most drivers' usage habits can reduce the probability of route deviation; those with good driving habits have fewer cases of deviations from the route; and complex traffic environments can enhance the probability of route deviation. The paper also proposes corresponding optimization suggestions for navigation application based on navigation application design factors.

Social factors also influence the use of navigation by drivers, specifically, the probability of route deviation decreases with increasing education. In addition, the negative correlation between education and the impact of the traffic environment suggests that the key point for a better traffic environment is the development of traffic awareness and quality of traffic participants, so that to improve traffic safety in society, drivers need to be systematically educated and trained, as well as social propaganda.

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References

1. Liu, P., Liu, Y.: Optimal information provision at bottleneck equilibrium with risk-averse travelers. Transp. Res. Rec. **2672**(48), 69–78 (2018)
2. Liu, Y., Nie, Y.: A credit-based congestion management scheme in general two-mode networks with multiclass users. Netw. Spat. Econ. **17**(3), 681–711 (2017). https://doi.org/10.1007/s11067-017-9340-7
3. Yared, T., Patterson, P., All, E.S.A.: Are safety and performance affected by navigation system display size, environmental illumination, and gender when driving in both urban and rural areas? Accid. Anal. Prev. **142**, 105585 (2020)

4. Yared, T., Patterson, P.: The impact of navigation system display size and environmental illumination on young driver mental workload. Transp. Res. F: Traffic Psychol. Behav. **74**, 330–344 (2020). https://doi.org/10.1016/j.trf.2020.08.027
5. Kaber, D.B., Liang, Y., Zhang, Y., Rogers, M.L., Gangakhedkar, S.: Driver performance effects of simultaneous visual and cognitive distraction and adaptation behavior. Transp. Res. F: Traffic Psychol. Behav. **15**(5), 491–501 (2012)
6. Hamish Jamson, A., Merat, N.: Surrogate in-vehicle information systems and driver behaviour: effects of visual and cognitive load in simulated rural driving. Transp. Res. F: Traffic Psychol. Behav. **8**(2), 79–96 (2005)
7. Zhao, W., Ma, Z., Yang, K., Huang, H., Monsuur, F., Lee, J.: Impacts of variable message signs on en-route route choice behavior. Transp. Res. Part A: Policy Pract. **139**, 335–349 (2020). https://doi.org/10.1016/j.tra.2020.07.015
8. Bumho, L., Yoo Jin, N.L., Sanghoo, P., Hyunsik, K., Su-Jin, L., Jinwoo, K.: Driver's distraction and understandability (eou) change due to the level of abstractness and modality of gps navigation information during driving. Procedia Comput. Sci. **39**, 115–122 (2014)
9. Larsson, J., Keskin, M.F., Peng, B., Kulcsár, B., Wymeersch, H.: Pro-social control of connected automated vehicles in mixed-autonomy multi-lane highway traffic. Commun. Transp. Res. **1**, 100019 (2021). https://doi.org/10.1016/j.commtr.2021.100019
10. Li, Y., Liu, Y., Xie, J.: A path-based equilibrium model for ridesharing matching. Transp. Res. Part B: Methodol. **138**, 373–405 (2020)
11. Gao, K., Yang, Y., Qu, X.: Diverging effects of subjective prospect values of uncertain time and money. Commun. Transp. Res. **1**, 100007 (2021). https://doi.org/10.1016/j.commtr.2021.100007
12. Uang, S.T., Hwang, S.L.: Effects on driving behavior of congestion information and of scale of in-vehicle navigation systems. Transp. Res. Part C: Emerg. Technol. **11**(6), 423–438 (2003). https://doi.org/10.1016/S0968-090X(03)00003-2
13. Large, D.R., Burnett, G.E.: The effect of different navigation voices on trust and attention while using in-vehicle navigation systems. J. Saf. Res. **49**(69), e61-75 (2014)
14. Lavie, T., Oron-Gilad, T., Meyer, J.: Aesthetics and usability of in-vehicle navigation displays. Int. J. Hum Comput. Stud. **69**(1), 80–99 (2011)
15. Dalton, P., Agarwal, P., Fraenkel, N., Baichoo, J., Masry, A.: Driving with navigational instructions: investigating user behaviour and performance. Accid. Anal. Prev. **50**, 298–303 (2013)
16. Rasker, P.C., Post, W.M., Schraagen, J.M.C.: Effects of two types of intra-team feedback on developing a shared mental model in command & control teams. Ergonomics **43**(8), 1167–1189
17. Ching-Torng, L., Hsin-Chieh, W., Ting-Yen, C.: Effects of e-map format and sub-windows on driving performance and glance behavior when using an in-vehicle navigation system. Int. J. Ind. Ergon. **40**(3), 330–336 (2010)
18. Liping, Y., Yang, B., Xiaohua, Z., Xiaoming, L., Xianglin, Y.: Drivers' acceptance of mobile navigation applications: an extended technology acceptance model considering drivers' sense of direction, navigation application affinity and distraction perception. Int. J. Hum. Comput. Stud. **145**, 102507 (2021)
19. Yang, B., Xiaolong, Z., Yiping, W., Xiaohua, Z., Hao, L., Yuelong, S.: Influence of prompt timing and messages of an audio navigation system on driver behavior on an urban expressway with five exits. Accid. Anal. Prev. **157**, 106155 (2021)
20. Ali, Y., Zheng, Z., Haque, M.M.: Modelling lane-changing execution behaviour in a connected environment: a grouped random parameters with heterogeneity-in-means approach. Commun. Transp. Res. **1**, 100009 (2021). https://doi.org/10.1016/j.commtr.2021.100009
21. Fu, C., Sayed, T.: Bayesian dynamic extreme value modeling for conflict-based real-time safety analysis. Anal. Methods Accid. Res. **34**, 100204 (2022)

22. Qi, W., Shen, B., Yang, Y., Qu, X.: Modeling drivers' scrambling behavior in China: an application of theory of planned behavior. Travel Behav. Soc. **24**, 164–171 (2021). https://doi.org/10.1016/j.tbs.2021.03.008
23. Pan, C., Xu, J., Fu, J.: Effect of gender and personality characteristics on the speed tendency based on advanced driving assistance system (ADAS) evaluation. J. Intell. Connected Veh. **4**(1), 28–37 (2021). https://doi.org/10.1108/JICV-04-2020-0003
24. Xu, Y., Ye, Z., Wang, C.: Modeling commercial vehicle drivers' acceptance of advanced driving assistance system (ADAS). J. Intell. Connected Veh. **4**(3), 125–135 (2021). https://doi.org/10.1108/JICV-07-2021-0011