Analysis of Driver's Emotion and Driving Performance during Music Listening using Physiological Indexes

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Abstract: Driver inattention, mainly due to drowsiness, is a significant factor in traffic accidents. Music is widely used to reduce a driver's drowsiness. There are various driving performances while listening to music. However, it is unclear what factors contribute to individual differences in driving performance. Therefore, this study investigates the factors contributing to individual differences in driving performance while listening to music. The experiment was conducted in two conditions: driving with and without listening to music using a driving simulator. We grouped drivers based on their driving performance and evaluated and compared the emotions between different groups. The results indicate that five out of seven participants in the low-driving performance group experience similar emotions: lower comfort and higher arousal. However, it is necessary to increase the number of participants to verify the results in future experiments.

Keywords: music, emotion, driving performance, physiological indexes

1. Introduction

Driver inattention is a significant factor in traffic accidents. According to the National Highway Traffic Safety Administration (NHTSA) report in 2019, 15% of police-reported crashes involve driver inattention [1]. Driver inattention occurs when drivers divert their attention from the driving task to focus on other activities. Drowsiness is one of the significant driver inattentions that impairs driving performance and results in crashes and fatalities. Therefore, it is necessary to prevent the driver from becoming drowsy and ensure that drivers pay attention to their driving.

Several methods can reduce drowsiness while driving effectively, such as listening to music, opening the windows, or switching on the air conditioner. Listening to music is the most popular activity for driver to reduce drowsiness and improve their concentration while driving. Previous study on the effect of music on driving suggest that listening to music can positively or negatively affect driving performance. Some studies report that driving with music can relieve boredom/fatigue [2], and enhance concentration [3] . Ünal et al. found that listening to music while driving increases driver's arousal, improves driving performance including lane control ability and speed [3]. Other studies report that music is a source of distraction and can affect driver's moods, which involve driving performance. Hughes et al. found that music impaired driver's hazard perception and increase mental workload [4]. Pêcher et al. evaluate the effect of music's emotional valence on driving behavior [5]. The results show that happy music distracted drivers, as decreased mean speed and deteriorated lateral control ability. The effects of music on driving are mixed and unclear. In our previous study [6], we compared emotions and driving performance between driving without and with music. The results showed that driving with music evoked more relaxed emotions and improved driving performance compared to driving without music. This indicates that different emotions can have different effects on driving performance. However, the results also show variations in driving performance while listening to music. Factors contributing to differences in driving performance are unclear. Therefore, this study aims to investigate the factors that contribute to individual differences in driving performance while listening to music. We hypothesized that driving while listening to music evoke different emotion for each participant, and similar emotions cause similar driving performances. This study focused on analysis of driver's emotions and driving performance during music listening. First, we conducted cluster analysis to group drivers based on their driving performance. Then, we evaluated driver's emotions using physiological indexes and compared emotions between different groups.

2. Experiment

This experiment aims to evaluate the driver's emotion and driving performance between two conditions: driving with and without listening to music. To ensure high validity in inducing positive emotions through music, participants were asked to choose their favorite music as emotion stimuli instead of selecting from a music database. During the music listening condition, participants repeatedly listened to the same music to prevent different emotional effects that may be evoked by different musics. The experiment conducted by using a fixed driving simulator with UC-win/Road software to create a low-complexity traffic environment and a monotonous two-lane highway. Participants were asked to maintain the center of the lane while driving and press a button on the steering wheel when recognize warning sign appeared on the screen.

Emotions are evaluate using a two-dimensional emotion model [7].Different emotions are associated with different combinations of arousal and valence. For example, happiness is associated with

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high arousal and positive valence, while anger is associated with high arousal and negative valence. Valence is defined as the level of comfort, where higher comfort corresponds to positive valence. We evaluate arousal and comfort using EEG and heart rate variability (HRV) indexes. HRV data were collected using a pulse wave sensor (SparkFun Electronics Inc.). We employed pNN50 as comfort indexes. The pNN50 is the time-domain HRV index that calculate by the proportion of successive RR intervals that differ by more than 50 msec. The higher pNN50 indicates the higher comfort level. We used a brainwave sensor; Mindwave Mobile 2 (NeuroSky Inc.) to collect EEG data. EEG signal is classified into several bands based on the frequency, including δ, θ, α, β, and γ. Generally, α represents relaxation, and β corresponds to alertness, the ratio of α and β was used to evaluate driver drowsiness. In this study, we employed β/α, as arousal indexes. The higher β/α indicates the higher arousal level[6].

Driving performance is evaluated using the Standard Deviation of Lateral Position (SDLP). SDLP is calculated using the offset from the center of the vehicle to the center of the road(meters), which can evaluate lane control ability. The higher SDLP indicates the greater lateral wobble.

2.1 Participants and Experimental procedure

Sixteen students (12 males and 4 females) in their 20s participated in the experiment. Before the experiment, the participants listened to an explanation and answered a questionnaire about their favorite music that can evoke comfort and arousal. Then, the participants wear the sensors. After that, participants practiced driving until they became familiar with the operation of the driving simulator. Then, the experiment procedure is as follows: (1) Participants rest for 1 minute. (2) They started driving according to a driving scenario. After taking 3-minute rest, participants repeated steps (1)-(2) with the condition of listening to the pre-selected music while driving.

3. Results and Discussion

The hierarchical clustering was performed on the average of SDLP to group the similar driving performance. Fig 1. presents a dendrogram showing the hierarchical clustering results of the SDPL during driving while listening to music. When setting the threshold to 0.2, the dendrogram can be divided into cluster 1 and cluster 2, with 7 and 9 members, respectively.

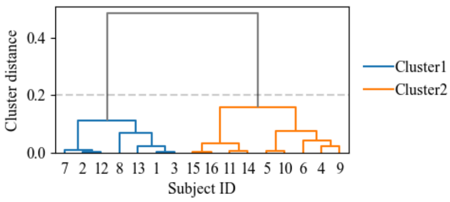

Fig. 1. Dendrogram showing the hierarchical clustering results of the SDPL during driving while listening to music.

To compare driver's emotion and driving performance between two cluster, we performed an independent samples t-test of β/α, pNN50, and SDLP. As a result, cluster 1(M=0.32, SD=0.1) had a significantly higher SDPL than cluster 2(M=0.2, SD=0.015); t (14) = 7.94, p < .001. This result indicated that cluster 1 had a poorer lane control ability than cluster 2. However, there are no significant difference in β/α, pNN50 between the two clusters.

We evaluated emotions using a two-dimensional emotion model. The x-axis of the model represents comfort, measured by pNN50, while the y-axis represents arousal, measured by β/α. Fig 2 presents a scatter plot of the average pNN50 and β/α for each participant while driving and listening to music. The origin of the graph represents the average pNN50 and β/α for all participants. Fig 3 shows that in cluster 2, there are differences and variations in pNN50 and β/α between participants. While in cluster 1, five out of seven participants had a lower pNN50 and higher β/α compared to the average of all participants. The results indicated that in cluster 1, five participants experienced the similar emotion which is lower comfort and higher arousal. Since driver in cluster 1 have similar driving performance which is poor lane control. These findings support our hypothesis that similar emotions cause similar driving performances. Moreover, the results suggest that emotion which associate with lower comfort and higher arousal could led to poor lane control. However, since the number of participants in each cluster is small, it is necessary to increase the number of participants to verify whether similar emotions can lead to similar driving performance.

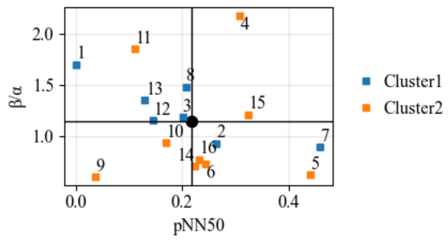

Fig. 2. scatter plot of the average of pNN50 and β/α

4. Conclusion

This study aims to investigate the factors that contribute to individual differences in driving performance while listening to music. We grouped drivers based on their driving performance and evaluated and compared the emotions between different groups. The results indicate that five out of seven participants in the low driving performance group experience similar emotions, with lower comfort and higher arousal.

Reference

[1] National Highway Traffic Safety Administration(NHTSA), "Distracted Driving in 2021".
[2] N. Dibben, et.al, "An exploratory survey of in-vehicle music listening" , Psychol. Music, vol. 35, no. 4, pp. 571–589,2007.
[3] A. B. Ünal, D. de Waard, K. Epstude, and L. Steg, "Driving with music: Effects on arousal and performance" , Transp. Res. Part F Traffic Psychol. Behav., vol. 21, pp. 52–65, Nov. 2013.
[4] G. M. Hughes, C. M. Rudin-Brown, and K. L. Young, "A simulator study of the effects of singing on driving performance" , Accid. Anal. Prev., vol. 50, pp. 787–792, Jan. 2013.
[5] C. Pêcher, C. Lemercier, and J.-M. Cellier, "Emotions drive attention: Effects on driver's behaviour" , Saf. Sci., vol. 47, no. 9, pp. 1254–1259, 2009.
[6] N. Jadram, et.al, "Evaluation of the Effect of Emotion on Lane-Keeping Performance Using Physiological Indexes," in HCI International 2023 – Late Breaking Papers, S, pp. 330–339,2023.
[7] Y. Ikeda, R. Horie, and M. Sugaya, "Estimating Emotion with Biological Information for Robot Interaction" , Procedia Comput. Sci., vol. 112, pp. 1589–1600, 2017.

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