The Effect of Natural Sounds and Music on Driving Performance and Physiological

Arafat Febriandirza, Wu Chaozhong, Ming Zhong, Zhaozheng Hu, and Hui Zhang

***Abstract*— Based on the current condition, we tend to investigate natural sounds, classical music and hard rock music effect on driving performance and physiological during simulated driving on highways. This paper was the first study that utilized natural sounds as a stimulus for driving behavior research. Participants (N = 98) were completed driving in the simulator without sounds, with natural sounds, classical music, and hard rock music. Furthermore, during 35-min each of driving conditions, we studied driving performance and physiological of participants. A mixed-ANOVA analysis showed that auditory stimulus has a significant multivariate effect on driving performance and physiological. This study shows driving performance was most efficient in listening natural sounds and most inaccurate in listening hard rock music. The result of perceived experiences shows that driving with natural sounds reported highest levels of control, concentration, enjoyment and lowest level of distraction. In contrast, driving with hard rock music reported lowest levels of control, concentration, enjoyment and highest level of distraction. In addition, the result of meditation analysis also indicated that relationship between auditory stimulus and driving performance was mediated by heart rate. Accordingly, the result of perceived experiences and physiological measures corroborates the driving performance measures.**

***Index Terms*— driving performance, heart rate, highways, music, natural sounds, perceived experiences**

I. Introduction

TODAY, driving is an essential as well as crucial part of public. With an increasing population, and vehicles congesting on transportation systems, there are more disruptions than ever before. Further, it's appears to be the trend for younger drivers to listen to loud volumes of hard rock music [1, 2]. Thus, the purpose of the current research appears to be a logical response to the current trend and growing driving population. By reviewing the literature and linking the effects of different types and volumes of sound to driving, it may be possible to bring an awareness to the importance of considering what to listen to while driving in terms of safety and performance.

Manuscript received March 04, 2017; This work was supported in part by China Scholarship Council under Grant Number 2013GF081 and National Nature Science Foundation of China (51178364, 61603282).

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Recent practice shows that driving an automobile is the main mode of transportation. Driving while listening to music is a growing popular practice than ever before. 91% of music exposure occur during transportation transits [4, 5]. Music has the proficiency to affect relaxation, the speed, or even driver stress while driving [6], and varieties of hard rock music are most frequently played in personal automobiles [7].

In addition, it has been suggested that listening to hard rock music relates to negative behaviors, for example traffic accidents and irresponsible driving through younger drivers [8, 9, 10]. It shows that listening to music facilitates driving performance [11, 12, 13]. Music has the ability to both positively and negatively influence driving performance [14]. It is uncertain whether or not music is helpful to driving and controlling an automobile. Thus, studying the effect of music on driving and the related tasks is an improving focus.

The literature shows inconsistency in reporting the findings on the effects background music has on driving related-tasks. Although it shows that music benefits driving performance and behavior, it still may be a major distraction and detrimental to driving abilities [15, 16, 17]. Furthermore, high excitement music may prevent driving performance because of rivalry for restricted handling space inside the cortex. During simulated driving, high arousing music decreased performance and increased lap times, it was discovered by North & colleagues. In this way, cognitive or driving related performance was reduced by higher arousing levels of music [18]. This current research will examine the effects of loud, moderate and quiet volumes and different kinds of sound, such as natural sounds, classical music and hard rock music, in order to make clear the contradiction.

An exploration of the restorative natural sounds heard at urban parks based on Attention Restoration Theory was done by Payne. It tested the participants' self-report of sounds they heard and their perceived restoration during their park visit. While it found participants to perceive themselves as only slightly restored when leaving the park, participants who visited urban parks were more frequently more conscious of soundscapes and had higher levels of considered recovery [19]. An examination of the correlation between sound and restoration by testing Perceived Restorative Soundscape Scale (PRSS) was continued by Payne. The scale is rarely because it tests restorative

(Advance online publication: 17 November 2017)

qualities of sound based on Attention Restoration Theory. The PRSS was found to be valid in measuring a sound's potential to provide restoration based on participants' self-report [20].

Self-reported measures of restoration were also used in a study that used qualitative methodology to explore the impacts of bird sounds to restoration [21]. Twenty participants were interviewed and asked to imagine being stressed and then to imagine a place that would facilitate restoration. It shows that 35% of the natural sounds which are mentioned by participants were bird sounds or calls, which were the most frequently mentioned natural sound. It suggests that bird sounds may assist in restoration. However, the researchers reasoned that further study is expected to better comprehend this relationship. Specifically, in order to obtain stronger results, quantitative data and a more detailed experiment are needed.

Emfield and Neider study the effects of auditory and visual environments on Attention Restoration Theory. Participants were brought into a laboratory, asked to complete a series of cognitive tasks to emulate mental fatigue. They were arbitrarily situated to a restoration period where they were subjected to one of six conditions: a mix of both sights and sounds, urban and natural scenery, natural sounds, and urban sounds. Compared to others who measure restoration, it was different because the natural images and sounds used were related to water (ocean scenery, sounds of wave lapping on the beach and seagulls). They were given the same series of cognitive tasks to measure restoration. It shows that there was no restoration effect on cognitive measures, but that the natural sights and sounds did improve mood, suggesting a more relaxing environment [22].

Another recent study, the effects natural sounds on mood were explored. In the previous studies, visual components have been used to addressing sound and restoration. It was different in which participants did not have visual stimuli and sounds were examined separately from visual. Participants viewed a disturbing video, with the intention of eliciting a negative mood and were then given different sounds to listen to (either natural or natural overlaid with anthropogenic sounds) in experiment. Before and after the listening treatment, mood was measured. Participants who were listening to natural sounds experienced an improvement in mood, suggesting that natural sounds can restore our emotions. Those findings provide evidence that natural sounds separate from visual nature can be restorative, like other studies that found viewing scenery to improve mood [23].

Nevertheless, does gender play a factor in the effect of music on performance? It has been indicated that males have superior visuomotor and visuospatial attention abilities contrasted to females [24]. Eagly and colleagues reported that during a visuomotor task females partook in the activity with greater cautiousness to reduce the number of errors related to the given task. Moreover, by nature males are all things considered more forceful than females [25].

Nowadays, music plays an important role in our daily life. The continuing expansion of the purpose of music beyond its conventional use of simply listening for entertainment provides many advantages to human life and behavior [26, 27]. Heart rate is what has affected by music and influenced human behavior [28, 29]. Our heart rate is the important organ that continuously pumps blood through the human body in a rhythmic pattern. Every person has a different constant rate that is controlled by the autonomic nervous system. This system is comprised of two types of nerves: the sympathetic nerves and the parasympathetic nerves [30]. Heart rate was higher because of stimulation of sympathetic nerves, and was slower due to stimulation of parasympathetic nerves [31].

Based on the explanation above, it is important to study the effects of natural sounds and music on driving performance and physiological. In line with findings on effects of natural sounds [20, 21, 22, 23] and hard rock music is correlated with negative behavior [8, 9, 10], we hypothesize that driving performance will be most efficient in listening natural sounds and most inaccurate in listening hard rock music **(Hypothesis 1).** Second, based on literature about gender [25, 26], we hypothesize that gender and interaction with auditory stimulus would have significant effect on driving performance and physiological **(Hypothesis 2).** In terms of perceived performance experience, we predict that listening natural sounds will result in highest levels of control, concentration, enjoyment and lowest levels of distraction. In contrast, exposure to hard rock music will result in lowest levels of control, concentration, enjoyment and highest levels of distraction **(Hypothesis 3)**. Lastly, in line with literature on heart rate affected by music and influenced human behavior [28, 29], we hypothesize that heart rate works as mediator variable in relationship between auditory stimulus and driving performance **(Hypothesis 4).**

II. Method

A. Participants

Ninety-Eight (N=98) participants (49 male and 49 female) from the university community offered to do the experiment, whose age ranged from 20 to 31 years (M = 24.47, SD = 2.03). The participants' mean driving experience was 5.3 years (SD = 1.24). There are no participants showed a history of hearing or visual impairments. All of the participants reported that they listen to music while driving. 55 % reported that they drive with music "all the time", and 45 % reported that they drive with music "most of time".

B. Apparatus

1) Driving Simulator

We utilized driving simulator of Intelligent Transportation Systems Research Center at Wuhan University of Technology, which owned a usual car control interface. The simulator giving a 180º view of the traffic environment and consists of three LCD screens. The driver's physical location relative to the virtual scene is recorded by the simulator, as x-y coordinates (m). The precision of these coordinates makes a possibility for simple derivation of standard lane maintenance variables, including standard deviation of lane position (SDLP). The data are compiled in the database of the main computer with a sample rate of 10 Hz. The driving simulator accumulates all streaming vehicle data generated by the driving simulation model, including speed, steering angle, and brake and accelerator force (See Fig. 1).

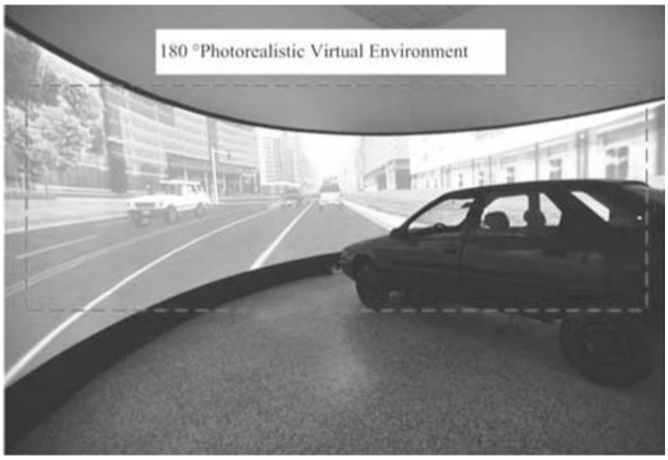

Fig. 1. Driving Simulator of Intelligent Transportation Systems Research Center at Wuhan University of Technology, China

2) Equivital Life Monitor

An ambulatory multi-parameter vital signs telemetry device aims at observing adults (16 years onwards) is called The Equivital™ LifeMonitor. The device is made up of a body worn sensor electronics module (SEM) connected to a fabric chest belt or adhesive skin electrodes. The heart rate, ECG data, respiration data, body orientation, skin temperature, activity and motion data were transferred and stored by tool. Additionally, device provides alerts and indications if physiology exceeds pre-defined boundaries and a patient operated event marker.

3) Auditory Stimulus Tools

Participants are presented to each auditory stimulus via stereo headphones that are linked to am/fm stereo receiver. The normal individual can be securely exposed to auditory stimuli at 95 dBA about one hour, in which it was stated by the National Institute for Occupational Safety and Health (NIOSH). During this experiment, participants were exposed about 35 minutes. Auditory stimuli levels were averaged via a pre-test to guarantee auditory stimuli levels fixed in NIOSH suggestions A sound level meter was located between the headphones for a five-minute length before the experimental session begins in order to control the average decibel level.

C. Experimental Design

There are four conditions while driving employed by the study. The repeated measures consist of four assessments in the driving simulator: (a) control condition, driving without sounds, (b) experimental condition, driving while listening hard rock music, (c) experimental condition, driving while listening classical music, (d) experimental condition, driving while listening natural sounds. In all assessments, the same driving route which is average complexity will be used, and it takes 35 min to complete each driving condition.

We used two lanes highways in each direction with a lane width of 3.5 m for the simulated environment. The environment is comprised with trees and monotonous, occasional hills and bridges as well as other traffic. (See Fig. 2). Participants were asked to drive with maintaining a steady speed of 90 km/h, while a steady lateral position in the right (slower) traffic lane. Whenever a participant approaches a slower moving car were allowed to overtaking maneuvers. Before analysis, these events will be eliminated from data.

Fig. 2. Simulated Environment of Experimental Design

D. Procedure

To familiarize them with the experimental design, the study begins with a training session to screen potential subjects. If they meet the consideration and rejection criteria, participants will have 15 min practice session in driving simulator. Simulator sickness will be completed using the Simulator Sickness Questionnaire during each session. Participants will be eliminated from participation if their have signs of simulator sickness.

The hearts of participants will be recorded during each 35-min driving test. Also, we will take two resting heart-rate estimations prior to and afterward each drive simulation. The non-active periods are not followed by sounds. Participants will finish a survey about their background information and demographics.

E. Dependent Variables

All dependent variables can be seen below in Table I. The main performance indicator was speed management (km/h), which is a measure the standard deviation of speed (SDS) in terms of responding to steady speed (90 km/h). Moreover, we also monitored lateral control, which is measured tracking errors, or involuntary (unconscious) response errors, calculated as the Standard Deviation of Lane Position (See Fig. 3).

Every 5 min of the 35-min simulated drive means SDS and SDLP were computed. Then, allowing us to detect any changes in driving performance over time as well, we calculated seven SDS and seven SDLP for each driving condition. Alike to procedure with driving performance indicator, mean Heart Rate scores were recorded based on 5 min intervals of the 35-min driving task. Accordingly, we calculated seven mean Heart Rate for each driving condition.

Participants will be rated their perceived experience after simulated driving each condition, which used Questionnaire on 11-point Likert-Scale (0=not at all, 5=moderately, 10=highly). Participants were asked, (1) “To what extend did you control on task driving during driving?”, (2) “To what extend did you concentrate on what is happening during driving?", (3) "To what extend did you enjoy the driving experience?" (4) "To what extend did you feel distracted during driving?"

TABLE I
DEPENDENT VARIABLES

	Dependent Variable	Collection Equipment	Units
Driving Performance Measures	Standard Deviation of Speed	Driving Simulator	Km/h
	Standard Deviation of Lane Position	Driving Simulator	Cm
Perceived Experience Measures	Control	Questionnaire	Likert
	Concentration	Questionnaire	Likert
	Enjoyment	Questionnaire	Likert
	Distraction	Questionnaire	Likert
Physiological Measures	Heart Rate	Equivital Life Monitor	BPM

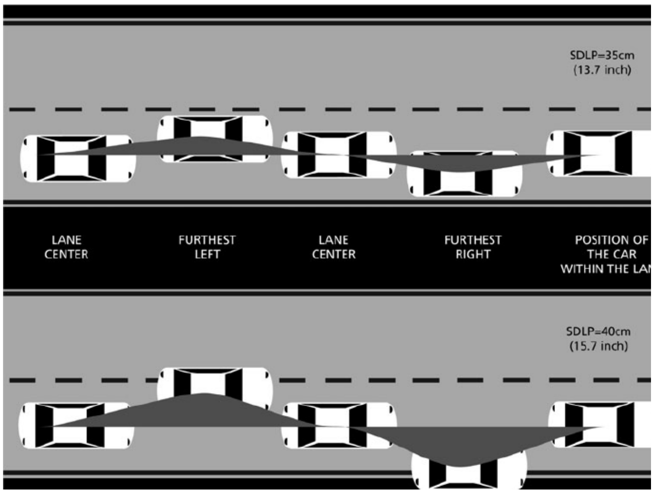

Fig. 3. The meaning of Standard Deviation of Lane Position (SDLP)

F. Independent Variables

Independent variables in this research were driving condition (no sounds, natural sounds, classical music and hard rock music) as within-subjects factor and Gender (male & female) as between-subjects factor. The list of auditory stimuli can be seen below in Table II.

G. Data Analysis

All the analysis of data was carried out using IBM SPPS version 23. Data were examined to address the objectives and hypotheses in Introduction. The analyses included within-subject comparisons in natural sounds, classical music, hard rock music and no sounds conditions and gender as between-subject comparison. In this way, we utilize a mixed-ANOVA model for information examination. First, to check whether the multivariate test was significant, we ran an overall mixed-ANOVA model. Second, if the multivariate test outcomes were significant, we ran separate mixed-ANOVA's to study the differences within conditions on Driving Performance (SDS and SDLP) and Physiological (Heart Rate), which were measured over 5 min intervals. For statistical significance, we set a significance level of .05 and we used partial eta square (η_p^2) to report the effect sizes.

In addition, we used a paired sample t-test to evaluate performance (SDS and SDLP), and perceived experience (control, concentration, enjoyment, and distraction) in each driving condition. Furthermore, we used mediation analysis to identify and explain the mechanism or process that underlies an observed relationship between auditory stimulus and driving performance (SDS and SDLP) via the inclusion of physiological (heart rate) as mediator variable. In the past study [32], Baron and Kenny have stated that mediation can only occur if three conditions exist: (a) the outcome variable has a statistically significant correlation with the predictor variable, (b) the mediating variable has a statistically significant correlation with the predictor variable, and (c) the mediator variable has statistically significant correlations with both the predictor variable and the outcome variable.

TABLE II
INDEPENDENT VARIABLES

Auditory Stimulus		
Natural Sounds	**Classical Music**	**Hard Rock Music**
Forest sound	Mozart- Piano Concerto	Black Sabbath – Ironman
Night sound	Beethoven - Symphony	Megadeth – Disintegrators
Sea sound	Vivaldi – The four seasons	Soil - The One
Cave sound	Chopin – Nocturne	Orgy – Blue Monday
Underwater world sound	Myers – Cavatina	Metallica - Sad But True
Snowstorm sound	Gounod - Ave Maria	Rammstein – Zwitter
Waterfall sound	Massenet – Meditation	Rob Zombie – Dragula
Fire sound	Wagner - The Valkyrie	Disturbed - The Game
Thunder sound	Barber - Adagio for Strings	Motley -Dr. Feelgood
Dolphins sound	Holst - The Planet	Hair of the dog – Rise

III. RESULT

A. Driving Performance Measures

A Mixed ANOVA was conducted to assess whether there were driving condition and gender differences in standard deviation of speed and standard deviation of lane position. The following assumptions were tested: (a) independence of observations, (b) normality, and (c) sphericity. Independence of observations and normality were met. The assumption of sphericity was violated, because estimate epsilon is less than 1.0. The "lower-bound" indicates the lowest value that epsilons could be. The highest epsilon possible is always 1.0. Typically, when epsilons are less than .75, use the Greenhouse-Geisser epsilon, but use Huynh-Feldt if epsilon ≥ .75. Thus, the Greenhouse-Geisser epsilon was used to correct degrees of freedom because epsilon is 0.69.

The Mixed ANOVA was run with SDS and SDLP scores while driving without sound, driving with natural sounds, driving with classical music, and driving with hard rock music as within-subjects factor and gender as between group factor. Results showed a statistically significant multivariate effect for SDS, F (2.1, 201.3) = 208.99, $p < 0.05$, η_p^2= 0.69, and statistically significant multivariate effect for SDLP, F (2.2, 210.5) = 251.94, $p < 0.05$, η_p^2= 0.72, which implies that there might be within-subject differences while driving without sounds and driving with natural sounds, classical music, and hard rock music over 35 min driving simulation.

Supporting hypothesis 1, driving performance will be most efficient in listening natural sounds and most inaccurate in listening hard rock music. As shown in Table III, a series of paired t-test revealed that participants had a slightly smaller standard deviation of speed while driving with natural sounds (SDS, M= *1.96*, SD= *0.17*) as compared to driving while listening hard rock music (SDS, M=*2.43* SD=*0.14*); $t(97)= -18.5$, $p<0.01$, and other driving condition, $p<0.05$. Moreover, Participants driving with natural sounds had a slightly smaller standard deviation of speed (SDLP, M=*20.22*, SD=*0.82*), in comparison to driving with hard rock music (SDLP, M=*22.80*, SD=*0.79*)); $t(97)= -20.41$, $p<0.01$ and other driving condition, p<0.05.

TABLE III
PAIRED T-TEST OF SDS AND SDLP IN EACH DRIVING CONDITION

Pair Driving Condition	SDS *t*	SDS *df*	SDS *r*	SDLP *t*	SDLP *df*	SDLP *r*
NoS - CM	9.37	97	0.69*	8.09	97	0.63*
NoS – NaS	14.3	97	0.82*	14.6	97	0.83*
NoS – HM	-11.1	97	0.75*	-13.13	97	0.78*
CM – NaS	8.45	97	0.65*	10.78	97	0.74*
CM – HM	-14.9	97	0.83*	-16.92	97	0.75*
NaS - HM	-18.5	97	0.88**	-20.41	97	0.90**

Note: NoS = No Sounds CM = Classical Music,
NaS = Natural Sounds HM = Hardrock Music
*$p<0.05$ **$p<0.01$

TABLE IV
MEANS SDS AND SDLP SEPARATELY BY GENDER

Driving Condition	SDS (s) Male (N=49)	SDS (s) Female (N=49)	SDS (s) Total (N=98)	SDLP (cm) Male (N=49)	SDLP (cm) Female (N=49)	SDLP (cm) Total (N=98)
No Sounds	2.25 (0.11)	2.24 (0.10)	2.25 (0.11)	21.76 (0.53)	21.73 (0.53)	21.75 (0.53)
Natural Sounds	1.95 (0.18)	1.97 (0.16)	1.96 (0.17)	20.13 (0.93)	20.31 (0.68)	20.22 (0.82)
Classical Music	2.07 (0.14)	2.09 (0.13)	2.08 (0.14)	21.28 (0.57)	21.22 (0.55)	21.25 (0.56)
Hard Rock Music	2.44 (0.14)	2.43 (0.13)	2.43 (0.14)	22.82 (0.81)	22.78 (0.79)	22.80 (0.79)

Note: Mean and standard deviation in the bracket are shown for each

Table IV provides the means and standard deviations for each driving condition separately by gender on SDS and SDLP. There was no main effect of gender on SDS (F *(1,96) = 0.56*, p = *0.46*, η_p^2 = *0.006*, *ns*) and SDLP (F *(1, 96) = 0.03*, p = *0.86*, *ns*). In addition, interaction between auditory stimulus and gender was again not statistically significant on SDS (F *(2.1, 201) = 0.32*, p= *0.73*, η_p^2 = *0.003*, *ns*) and SDLP (F *(2.2, 210.5) = 0.69*, p= *0.52*, η_p^2 = *0.007*, *ns*). Therefore, Hypothesis 2, interaction between auditory stimulus and gender would have significant effect on driving performance and physiological was not supported.

Furthermore, we ran separate mixed-ANOVAs for each of the 5-min intervals of the simulated drive to explored the difference in SDS (see figure 4) and SDLP (see figure 5), while driving without sounds, driving with natural sounds, driving with classical music, and driving with hard rock music.

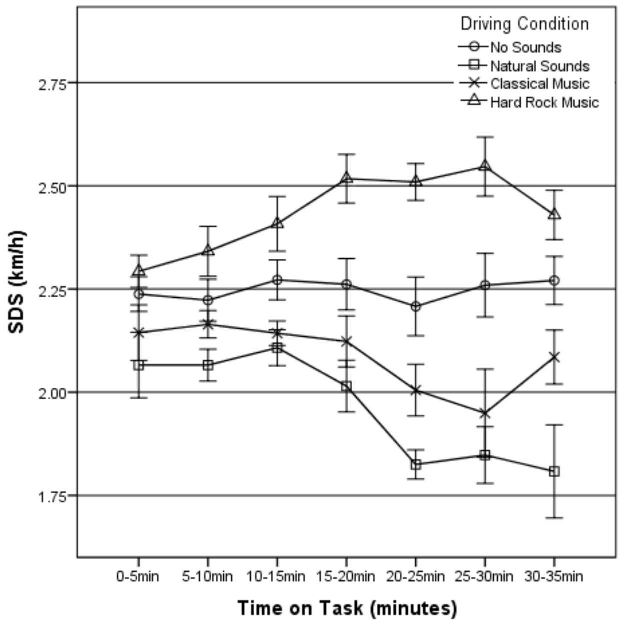

Fig. 4. Standard Deviation of Speed in each driving condition.
Bars represents the standard errors for the means.

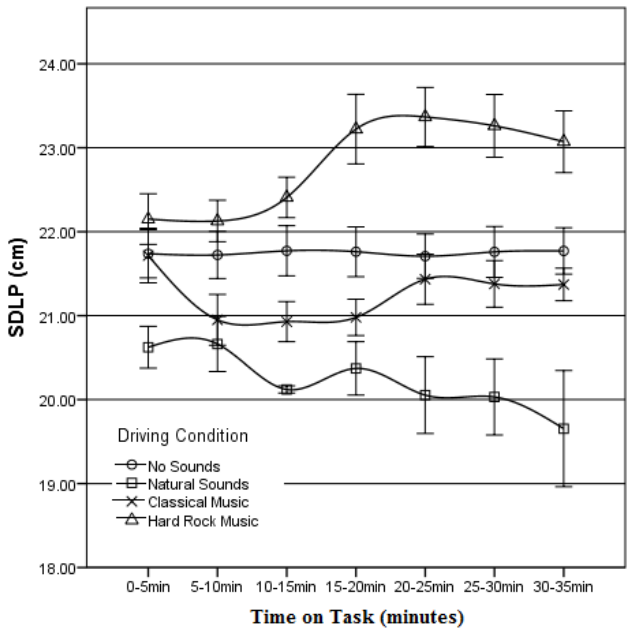

Fig. 5. Standard Deviation of Lane Position in each driving condition.
Bars represents the standard errors for the means.

B. Perceived Experience Measures

Table V presents the mean experience ratings following performance in each driving condition.

TABLE V
MEANS PERCEIVED EXPERIENCE MEASURES IN EACH DRIVING CONDITION

Driving Condition	Control	Concentration	Enjoyment	Distraction
No Sounds	4.24 (0.66)	4.34 (0.73)	4.32 (0.65)	5.04 (0.59)
Natural Sounds	8.62 (0.51)	8.85 (0.62)	8.95 (0.63)	3.62 (0.87)
Classical Music	6.51 (0.50)	6.68 (0.62)	6.59 (0.59)	4.45 (0.52)
Hard Rock Music	3.09 (0.70)	3.27 (0.68)	3.38 (0.62)	8.27 (0.65)

Note: Mean and standard deviation in the bracket are shown for each parameter

TABLE VI
PAIRED T-TEST OF CONTROL AND CONCENTRATION

Pair Driving Condition	Control			Concentration		
	t	*df*	*r*	*t*	*df*	*r*
NoS - CM	-36.26	97	0.96*	-27.31	97	0.94*
NoS – NaS	-82.09	97	0.97**	-49.02	97	0.98**
NoS – HM	12.36	97	0.78*	13.89	97	0.82*
CM – NaS	-44.14	97	0.98**	-28.87	97	0.95**
CM – HM	38.78	97	0.94*	42.38	97	0.95*
NaS - HM	64.26	97	0.98**	60.15	97	0.98**

Note: NoS = No Sounds CM = Classical Music,
NaS = Natural Sounds HM = Hardrock Music
*$p<0.05$ **$p<0.01$

As shown in Table VI, a series of paired sample t-tests were conducted to evaluate the hypothesized impact of auditory stimulus on perceived control and concentration. There was a main effect of auditory stimulus on control, $F(2.1, 203.1) = 2198$, $p < 0.05$; $\eta_p^2 = 0.958$. As hypothesized, participants felt greatest control when exposed to natural sounds (*M=8.62, SD=0.51*) in comparison to the other conditions ($p < 0.01$, for all). And participants indicated least control during exposure to hard rock music (*M=3.09, SD=0.70*) in comparison to the other sound conditions ($p < 0.05$). Therefore, hypothesis 3 was supported.

There was a main effect of auditory stimulus on concentration, F (2.8, 275.6) = 1752, p < 0.05; $\eta_p^2 = 0.95$. As hypothesized, rating of concentration was highest in natural sounds (*M = 8.85, SD = 0.62*) in comparison to the other sound conditions ($p < 0.01$, for all). In contrast, rating of concentration was lowest in hard rock music (*M = 3.27, SD = 0.68),* in comparison with the other sound conditions ($p < 0.05$, for all). So, hypothesis 3 was supported.

Figure 6 presents the mean ratings of control and concentration following performance in each driving condition. It can be seen that when exposed to natural sounds, participants reported high levels of control and concentration. In contrast, it can be seen that when exposed to hard rock music, participants reported lowest levels of control and concentration for the driving task, as predicted.

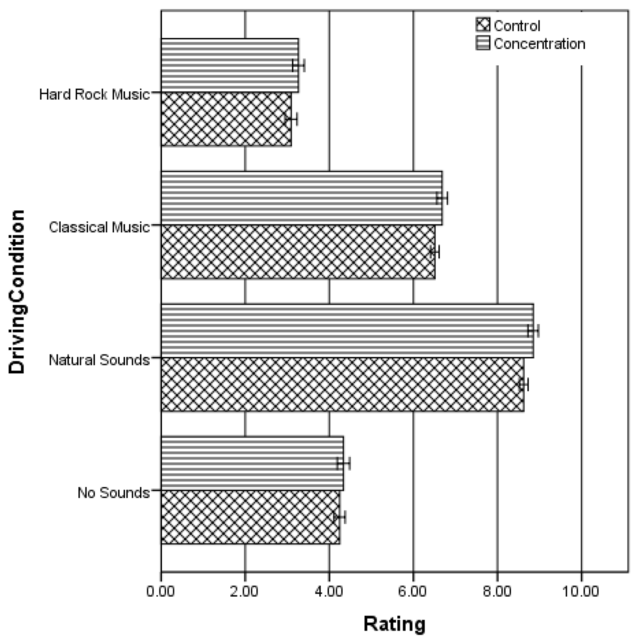

Fig. 6. Means rating of control and concentration in each driving condition. Bars represents the standard errors for the means.

TABLE VII
PAIRED T-TEST OF ENJOYMENT AND DISTRACTION

Pair Driving Condition	Enjoyment			Distraction		
	t	*df*	*r*	*t*	*df*	*r*
NoS - CM	-25.19	97	0.93*	7.12	97	0.59*
NoS – NaS	-50.89	97	0.98**	12.84	97	0.79**
NoS – HM	11.47	97	0.75*	-38.98	97	0.97*
CM – NaS	-25.61	97	0.93**	8.31	97	0.64**
CM – HM	40.29	97	0.97*	-53.32	97	0.98*
NaS - HM	57.91	97	0.98**	-39.03	97	0.97**

Note: NoS = No Sounds CM = Classical Music,
NaS = Natural Sounds HM = Hardrock Music
*$p<0.05$ **$p<0.01$

As shown in Table VII, a series of paired sample t-tests were conducted to evaluate the hypothesized impact of auditory stimulus on enjoyment and distraction. There was a main effect of auditory stimulus on enjoyment, F (2.9, 287.8) = 1576, p < 0.05; $\eta_p^2 = 0.94$. As hypothesized, rating of enjoyment was highest in natural sounds (M = 8.95, SD = 0.63) in comparison to the other sound conditions (p < 0.01, for all). In contrast, rating of enjoyment was lowest in hard rock music (M = 3.38, SD = 0.62), in comparison with the other sound conditions (p < 0.05, for all). So, hypothesis 3 was supported.

There was a main effect of auditory stimulus on distraction, $F(2.4, 236.4) = 899.43$, $p < 0.05$; $\eta_p^2 = 0.90$. A series of paired sample t-tests were conducted to evaluate the hypothesized impact of auditory stimulus on perceived distraction. As hypothesized, participants felt least distracted when exposed to natural sounds (*M=3.62,* *SD=0.87*) in comparison to the other conditions ($p < 0.01$, for all). And participants indicated greatest distraction during exposure to hard rock music (*M=8.27, SD=0.65*) in comparison to the other sound conditions ($p < 0.05$). Therefore, hypothesis 3 was supported.

Figure 7 presents the mean ratings of distraction and enjoyment following performance in each driving condition. It can be seen that when exposed to hard rock music, participants reported highest levels of distraction and lowest levels of enjoyment. In contrast, it can be seen that when exposed to natural sounds, participants reported high levels of enjoyment for the task and low levels of distraction, as predicted.

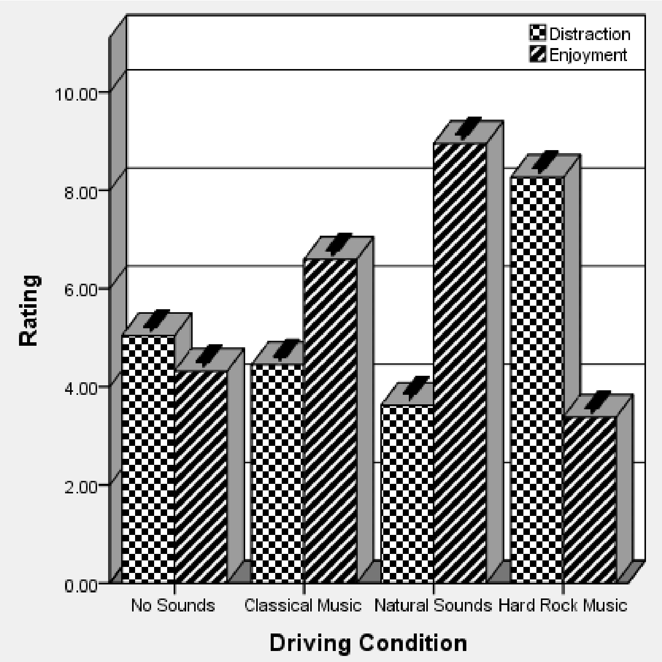

Fig. 7. Means rating of enjoyment and distraction in each driving condition. Bars represents the standard errors for the means.

C. Physiological Measures

A Mixed ANOVA was run with heart rate score while driving without sounds, driving with natural sounds, driving with classical music, and driving with hard rock music as within-subjects factor and gender as between subject factor. Results show a statistically significant multivariate effect for heart rate, $F (2.34, 224.8) = 796.12$, $p < 0.01$, $\eta_p^2 = 0.892$, which implies that there might be within-subject's differences while driving without sounds and driving with natural sounds, classical music, and hard rock music over 35 min long drive. There was no main effect of gender on heart rate (*F (1, 96) = 0.20, p = 0.65, ns)*. Moreover, interaction between auditory stimulus and gender was again not statistically significant on heart rate ($F (2.34, 224.8) = 0.197$, $p=0.85$, $\eta_p^2 = 0.002$, *ns)*. Therefore, Hypothesis 2, interaction between auditory stimulus and gender would have significant effect on driving performance and physiological was not supported.

Statistical mediation analysis which uses Hayes Syntax [33] was conducted to determine if heart rate mediates the relationship between auditory stimulus (no sounds, natural sounds, classical music, and hard rock music) and driving performance (standard deviation of speed and standard deviation of lane position) (SDS). Assumptions of uncorrelated errors, normally distributed errors, and linearity were checked and met.

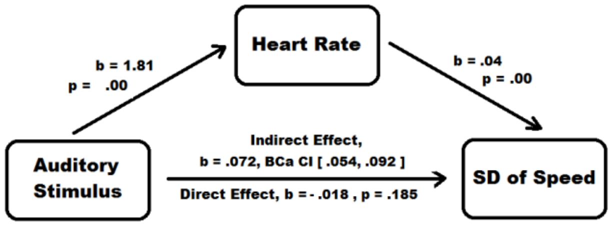

Fig. 8. Model of auditory stimulus as a predictor of SDS, mediated by heart rate

Figure 8 shows the b's and p values for the effects of relationship auditory stimulus and standard deviation of speed, which heart rate as mediator. This model shows that the relationship between auditory stimulus and standard deviation of speed was not a direct effect but operates through heart rate. There was not significant direct effect of auditory stimulus on standard deviation of speed, *b = - .018, p = .185*. The model information also shows that auditory stimulus statistically significantly predicts heart rate, *b* = 1.81, *p* = .00, and heart rate statistically significantly predicts standard deviation of speed, *b* = .04, *p* = .00.

Accordingly, the result shows heart rate did statistically significantly mediate the relationship between auditory stimulus and standard deviation of speed. There was actually a significant indirect effect of auditory stimulus on standard deviation of speed mediated by heart rate, *b = .072, BCa CI [.054, .092],* The confidence interval doesn't contain zero, then we can conclude that mediation has occurred which supported hypothesis 4.

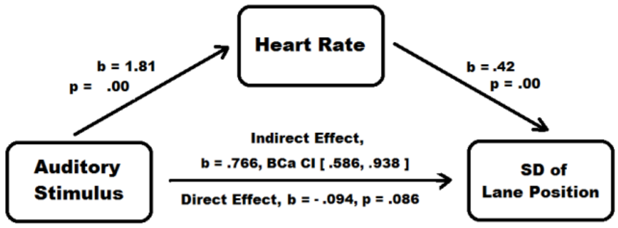

Fig. 9. Model of auditory stimulus as a predictor of SDLP, mediated by heart rate

As shown figure 9, indicates that the relationship between auditory stimulus and standard deviation of lane position was not direct effect but proceeded through heart rate. There was not significant direct effect of auditory stimulus on standard deviation of lane position, *b = - .094, p = .086*. The model information indicates as well that auditory stimulus statistically significantly predicts heart rate, *b* = 1.81, *p* = .00 and heart rate statistically significantly predicts standard deviation of lane position, b = *.42*, p = *.00.*

According to the result, heart rate did statistically significantly mediate the relationship between standard deviation of lane position and auditory stimulus. The significant indirect effect of auditory stimulus on standard deviation of lane position through heart rate was found, *b = .766, BCa CI [.586, .938]*. The confidence interval doesn't contain zero, therefore it can be concluded that mediation did occur, in which hypothesis 4 was supported.

IV. Discussion

According to the first hypothesis, driving performance will be most efficient in listening natural sounds and most inaccurate in listening hard rock music. We found that drivers' speed and lateral control was relatively better in listening natural sounds than in other sounds, as designated by a somewhat smaller SDS and SDLP during 35 min driving while listening natural sounds. In contrast, SDS and SDLP have higher scores while driving with hard rock music. Therefore, hypothesis 1 was supported.

As stated by second hypothesis, that interaction between auditory stimulus and gender would have significant effect on driving performance and physiological was not supported. There was no main effect of gender, while interaction between auditory stimulus and gender was not significant according to test of within-subject effects. This effect shows that the impact of auditory stimulus (without sounds, natural sounds, classical music, and hard rock music) on driving performance (SDS and SDLP) and physiological (heart rate) was not different in comparison with gender (male and female).

On third hypothesis, in term of perceive experience measures, that listening natural sounds will result in highest levels of control, concentration, enjoyment, and lowest level of distraction. In contrast, exposure to hard rock music will result in lowest levels of control, concentration, enjoyment, and highest level of distraction, it was supported. In addition, these experience measures confirm the performance measures above. Performance and experience were optimal when exposed to natural sounds which was control, concentration, and enjoyment for the task driving. In contrast, performance was poorest and the experience was least control, concentration, and enjoyment when exposed to hard rock music which was distracting for the listening context.

The last hypothesis, that physiological (heart rate) mediates the relationship between auditory stimulus and driving performance (SDS and SDLP) was supported. Heart rate as mediator variable, was served to clarify the nature of the relationship between auditory stimulus and driving performance (SDS and SDLP). In addition, auditory stimulus statistically significantly predicts heart rate, and heart rate statistically significantly predicts driving performance (SDS and SDLP). The model detail can be seen in Figure 8 and Figure 9.

V. Conclusion

This study was aimed at exploring how music and natural sounds influence driving performance and physiological during simulated driving on highways. The result of mixed-ANOVA analysis showed that the auditory stimulus has a significant multivariate effect on driving performance and physiological. Our findings indicate that driving with natural sounds consistently affected performance in relation with speed management and lane-keeping control that are better than driving with hard rock music.

In addition, there were no significant main or interaction effects involving gender on driving performance and physiological. Furthermore, we found out that driving while listening to natural sounds gave drivers some perceived control, concentration, and enjoyment which might be helpful to be attentive while conducting monotonous driving assignment in complex traffic settings. Moreover, we also found that heart rate functions as mediator variable in relationship between auditory stimulus and driving performance. Accordingly, the result of perceived experience and physiological measures corroborate the driving performance measures.

Based on our findings, it suggests that listening to natural sounds would be a good strategy to halt boredom and to meet the need for stimulation, while someone was busy with monotonous driving tasks. Potential safety effects of listening to natural sounds and music during longer journeys could be explicitly focus in the future studies.

Acknowledgment

The authors want to thank the volunteer drivers for their participation in the experiment, researchers: Dr. HE Yi, Mr. GAO, and students in Intelligent Transportation Systems Research Center at Wuhan University of Technology for their technical assistance.

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