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ORIGINAL ARTICLE

The effect of listening to Iranian pop and classical music, on mental and physiological drowsiness

Niloofar Sheibani[1] · Seyed Abolfazl Zakerian[1] · Iraj Alimohammadi[2] · Kamal Azam[3] · Elham Akhlaghi Pirposhteh[4]

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Abstract

Driver's drowsiness is one of the high-risk road behaviors that quadruples the risk of road accidents. Measures to deal with drowsiness during driving include listening to music. The present study investigates the effect of two types of music, namely Iranian high-tempo pop and classical music, on mental and physiological drowsiness during driving. Twelve male students at Tehran University of Medical Sciences within the normal range of the Epworth Drowsiness Scale (ESS) participated in this study. Two types of music (classical and pop) were assessed on two separate days with an interval of one week. The mental aspect of drowsiness was evaluated using the Karolinska Sleepiness Scale (KSS), the physiological aspect by monitoring the EEG and heart rate, and the functional aspect through the mean and standard deviation of speed and the Standard Deviation of Lateral Position (SDLP) in a driving simulator. The results showed that the brain waves (four algorithms (1) $(\theta+\alpha)/\beta$, (2) α/β, (3) $(\theta+\alpha)/(\alpha+\beta)$ and (4) θ/β), the KSS score, SDLP and standard deviation of speed all decrease while the mean heart rate increases when listening to music during driving compared to driving without music. No significant difference was observed in the mean speed when exposed to music. Moreover, no difference was observed between the effect of the two music styles, i.e. Iranian classical and pop music. Listening to Iranian classical and pop music while driving improves the driver's performance and reduces drowsiness. The present study showed that higher tempo music during driving can reduce drowsiness and change physiological responses and driving performance.

Keywords Drowsiness · SDLP · EEG · Heart rate · KSS

✉ Seyed Abolfazl Zakerian
zakerian@tums.ac.ir

Niloofar Sheibani
niloofarsheibani94@gmail.com

Iraj Alimohammadi
irajrastin1@gmail.com

Kamal Azam
kazam@tums.ac.ir

Elham Akhlaghi Pirposhteh
e.akhlaghi3@yahoo.com

1 Department of Occupational Health, School of Health, Tehran University of Medical Sciences, Tehran, Iran

2 Department of Occupational Health, School of Public Health, Iran University of Medical Sciences, Tehran, Iran

3 Department of Epidemiology and Biostatistics, School of Health, Tehran University of Medical Sciences, Tehran, Iran

4 Department of Occupational Health and Safety at Work Engineering, School of Medical Sciences, Tarbiat Modares University, Tehran, Iran

Introduction

Over 1.2 million people lose their life in road accidents around the world every year [1]. Studies have shown that driving while drowsy has a significant relationship with road accidents [2, 3]; in fact, drowsiness quadruples the risk of driving accidents [4]. Drowsiness-related road accidents cause substantial loss of money and lives [5, 6] According to the U.S. National Highway Traffic Safety Administration, between 56,000 and 100,000 accidents that are a direct result of drowsiness happen every year, leading to over 1500 deaths and 71,000 injuries [2].

Driver's drowsiness depends on several factors, including the quality of sleep the night before, the circadian rhythm (at the test time), and the driving task complexity (monotonous or difficult) [7]. The lack of sleep can reduce attention and alertness by up to 50%, decision-making ability, communication skills and memory [8]. Furthermore, drowsiness reduces the speed of response to stimuli and accuracy in driving [9]. Research shows that driving, particularly on routine and repetitive routes, is a single-task operation that can lead to unpleasant situations, such as fatigue and drowsiness [10].

A drowsy driver loses the control of the vehicle, and this failure often leads to an accident with other vehicles, people, or objects. Drivers' drowsiness must be controlled to avoid such devastating accidents. There are many tools for assessing drivers' drowsiness, including functional scales, such as Steering Wheel [11] Behavior-Based Estimation of Fatigue, Standard Deviation of Lateral Position (SDLP) [12], yawning and blinking [13], and mental assessments (the Karolinska Sleepiness Scale (KSS) and the Stanford Sleepiness Scale(SSS)) [14], and physiological measurements [15]. Many physiological factors have been suggested for detecting drowsiness, including ocular activities [16], heart rate [17], electrical skin potential [18], and electroencephalography (EEG) [19]. Among biological indicators, EEG signals are the safest methods for predicting and detecting drowsiness, since they measure the brain's responses directly [20]. Each of these methods has their own strengths and weaknesses, and applying a combination of psychological parameters, such as self-reports and physiological measurements, can yield the most accurate results [20].

Although sleeping is the most effective method of reducing drowsiness, continuing driving is inevitable in some cases, and certain interventions appear necessary for dealing with drowsiness. Measures to deal with drowsiness in the vehicle are those taken by the driver to become more alert. These measures can include drinking caffeinated drinks, such as tea or coffee, listening to the radio or music, taking turns in driving (using an assistant driver), opening the windows or switching on the air conditioner [21]. Listening to the radio or music, opening the windows, or switching on the air conditioner are popular measures among drivers and are more effective than roadside warning signs [22].

Among the different secondary tasks performed by drivers while driving, listening to music or the radio is the most popular [23]. An observational study conducted on American drivers showed that music (mostly on the radio) is played in vehicles 72% of the time [24]. Listening to music boosts the person's mood [25], working memory [26], and the data processing ability [27]. In many cases, music is used by drivers as a measure to deal with the complexity of their tasks and to enhance their concentration [28]. Interestingly, according to the results obtained by [29] drivers reported that they listen to music to kill time while driving. Therefore, in many cases, drivers listen to music due to the monotony of driving as an activity and the lack of sufficient external stimuli [10]. Studies confirming this observation have shown that, during monotonous driving, music does not only impair performance, but also improves it and increases the motivation in many cases [30].

Music, especially high-energy music, such as loud high-tempo music, can be highly provocative based on mental and physiological reports [31]. The classical music belonging to any society is indicative of its culture and background. Cultural differences in the perception and functions of music have been assessed by ethnic music experts and cognitive psychologists, and in psychological studies of music, many researchers and anthropologists have shown an interest in the study of the music specific to the culture of that community [32]. On another note, popular or pop music refers to any style of music that is commercially available to the general public. Pop music is in contrast with classical and folklore music. With the advances in technology, the interest in pop music (especially given its general appeal to the public) has been growing in recent years [33]. These two styles of music can thus be said to be the exact reverse of each other, and they have been examined in comparison with each other in some studies in the past [25], and further studies are required on this subject. Iranian classical and pop music were therefore chosen in the present study.

Given the discussed issues and the importance of safe driving and also the heavy damages imposed by driving accidents occurring due to fatigue and drowsiness, and the effect of music as a strategy to overcome drowsiness, conducting more studies on the subject appears necessary. Very few studies have assessed the effect of listening to music on drivers' drowsiness, and the subject matter of these limited studies has also differed from the present study's subject. Considering that most road accidents caused by drowsiness occur among 16- to 25-year-old male drivers [34], the present study was conducted on male students to assess how music effect on driver's drowsiness in a simulated environment. The mental aspect of drowsiness was assessed using the Karolinska Sleepiness Scale (KSS), the physiological aspect by monitoring the EEG and heart rate, and the functional aspect by the mean and standard deviation of speed and SDLP.

Materials and methods

Participants

Twelve male students of Tehran University of Medical Sciences, with an age range of 20–25 years and a BMI[1] of 22.77 ± 2.81, participated in the study. The study inclusion criteria were: having a driver's license (at least one year since its date of issue) and having no history of cardiovascular diseases, brain trauma or disease, sleep disorders, seizure, asthma or pulmonary diseases, hypertension, and

[1] Body mass index.

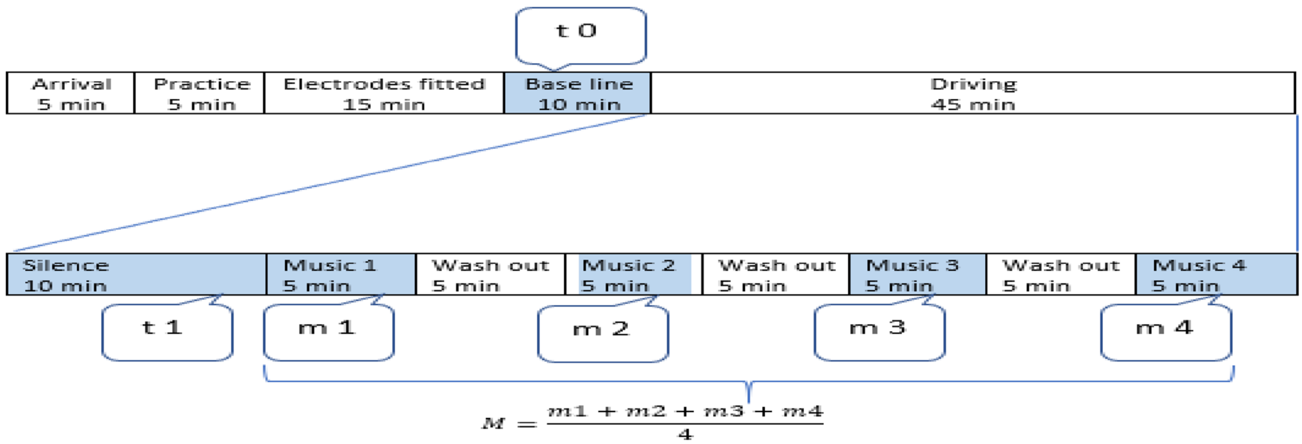

Fig. 1 The process of experiment in each day. Conditions contain: (1) t0 represent base line. (2) t1 represent driving without music or silence. (3) M is driving with music (the average of four music)

hearing or vision problems. They were not musicians either and had no experience of playing musical instruments, and had a previous experience of feeling drowsy while driving. After obtaining their informed written consent, they were asked not to sleep from 12 h before the test and to have no caffeinated beverages, such as tea or coffee, and refrain from smoking or using any kind of stimulants.

All the participants had a regular sleep pattern (sleeping before 1 am and waking before 9 am and no habit of daytime napping). The other inclusion criteria were: Score < 10 in the Epworth Drowsiness Scale (ESS) [35], which was completed by all the participants and they all obtained acceptable and normal scores (0–10). In this study, the Farsi version of this questionnaire was used, which has an internal consistency of 82–88% based on Cronbach's alpha coefficient [36]. The general process of the test was explained for all the participants. All the tests were administered between 7 and 9 am.

Study design

The present study was conducted on two different days under completely similar conditions. The classical and pop music groups were assessed single-blind and randomly on two different days, so that each participant listened to pop music on one day and classical music on another, with a week's interval between these two days. The participants presented to the laboratory at 7 am on both days, and the method of experiment was such that each subject drove a driving simulator on a trial basis, and then a chest sensor was connected, and the device was switched on. The actual driving scenario, lasting 45 min, began following the QC[2] testing, basal EEG rhythm testing, and headphone testing.

Based on the research background and other studies [37], about 10 min were required at first to record the basal rhythm and develop the initial fatigue and monotony. Ten minutes later, the first music was played for the participant. Each music was played for 5 min. In the study by [38], a 5-min interval was given between each piece of music to remove the effect of transition, and the same interval was applied in this study as well. Therefore, the second, third, and fourth music were played with 5-min intervals between them. This timing was observed for all the participants on both the pop and classical music days. The order of playing four music of each style was predetermined and the same for all participants. It should be noted that these stages caused no disruption in the subject's driving; i.e. the subject drove continuously during the entire time (45 min) while his EEG signals, heart rate and KSS were taken, and the experiment had a fully continuous process. (Fig. 1).

Music

Given that high-tempo music is recognized as a stimulus [23]; the main criterion for selecting music pieces was having a high tempo, i.e. between 120 and 140 BPM. A noteworthy point is that tempos higher than this level cause deviation from the path and inattention to traffic lights and therefore increase the risk of road accidents [39]. Since the intensity of the music (i.e. loudness of the sounds) affects humans' performance while driving and also since a sound intensity level in the 70 dB range has been reported as acceptable and non-disturbing for users [40], the level of sound loudness was adjusted through an octave band leq (the Equivalent Continuous Sound) analysis in the range of 70 dB, except for no-music conditions. The vehicle engine noise and road noise were set at 25 dB in all the conditions. Another point was the duration of each track, which was

[2] Quality Control.

also considered in selecting the music, and all tracks had a playing time of 5 min.

Simulator

Since the study of real-time driving by a drowsy driver is ethically controversial and unsafe, the researchers conducted their experiment using a simulated environment. The main benefits of using simulators include having total control over the experiment, high efficiency, low costs, safety, and ease of data collection [8]. A key limitation in the use of driving simulators is that drivers do not perceive any danger. Knowledge of being immersed in a simulated environment may lead to a behavior that is different from that pursued on the road in real time [41]. In this experiment, the driving simulator was used in a quiet room with controlled temperature and noise levels and fixed lighting.

Before beginning the data collection, the participants were invited to take a practice run at the driving simulator. The first 5-min session helped familiarize the participants with the road and the simulator environment and included explanations about how to drive. The required scenario included a three-lane freeway with minimum traffic congestion. The points with which the participants had to comply included driving on a straight line, particularly in the middle lane, and maintaining a constant speed of 70–90 km/h to make the drive monotonous for the subjects. To further make the drive monotonous, the examiner set the vehicle in automatic transmission. The participants were asked to reach the required speed within 1 min, stay in the middle lane, and observe all the noted points along the route. The actual experiment was held after the initial 5-min practice.

The driving variables in the analysis included the mean and standard deviation of speed, the Standard Deviation from Lateral Position (SDLP), and the mean speed. Lateral position is defined as the difference between the center of the subject's vehicle and the center of the driving lane in meters.

Mental assessments

The Karolinska Sleepiness Scale (KSS) assesses the level of sleepiness at a specific time during the day. In this scale, the participants identify which level best reflects the psycho-physical state experienced in the last 10 min. The scale is scored from 1 (extremely alert) to 9 (very sleepy). The KSS was designed by [42] and has high levels of validity and reliability. The KSS was fully described to the participants before the test. The participants are asked to answer the items of the scale once at rest time (t0) as the basal rhythm, at the end point (t1), and after each track is played (m1, m2, m3, and m4) and the examiner records their answers (Fig. 1).

Physiological outputs

Heart rate

Heart rate has recently been studied to detect drivers' drowsiness [43]. This technique can also be used for assessing the effect of music on drowsiness. The subjects' heart rate was monitored during the experiment using a Beurer pulse meter (PM70 model). This device consists of a sensor mounted on the chest and a clock display. The heart rate rhythm was initially measured every minute in the first 10 min when the person was resting, and its mean value was taken as the basal rhythm. It was then recorded every minute during driving, and the mean value of the required times was calculated.

EEG The electrodes were attached according to the 10–20 protocol. A signal was recorded by a 16-channel g.tec USB-amp and Simulink version 1/16/01 by g.tec Company in MATLAB 2017. In this study, the sampling frequency was chosen as 256 Hz, the high-pass filters as 0.5 Hz, the low-pass filters as 60 Hz, and the notch filter as 50 Hz. These were then recorded as the basal rate of alertness while the participant was comfortably seated in a chair for 10 min [44] with his eyes open and observing images on the simulator monitor, and they were also recorded consistently throughout the actual driving experiment. The EEG data were pre-processed using the latest EEGlab version. The extended ICA (Independent component analysis) algorithm [45] was used to minimize the effect of muscle activity, blinking, and technical noise. Next, the properties were extracted to differentiate between the "alert" and "drowsy" states. The filtered data were initially divided into 2-s epochs. In recent years, researchers have used different methods [19, 37, 38] to extract the linear and nonlinear properties of EEG waves to detect fatigue and drowsiness. One method for extract properties from EEG is frequency power decomposition through Fast Fourier transform (FFT). The variations in the four algorithms (1) $(\theta+\alpha)/\beta$, (2) α/β, (3) $(\theta+\alpha)/(\alpha+\beta)$ and (4) θ/β constitute an acceptable measure for detecting fatigue [37]. All these algorithms increase when the subject is drowsy, and the highest variation is observed in algorithm (1), i.e., $(\theta+\alpha)/\beta)$ [46]. In the present study, the rhythm of these four algorithms by the mean entire brain (in the recording channels) was reported as the final EEG index.

Data analysis

Data were analyzed in SPSS-23. The physiological, mental, and functional scales were ultimately grouped in three general categories, including basal rate (before beginning driving), the first 10 min of driving (without music), and with music played. Then, they were compared two by two using the paired *T* test. Next, the three independent music

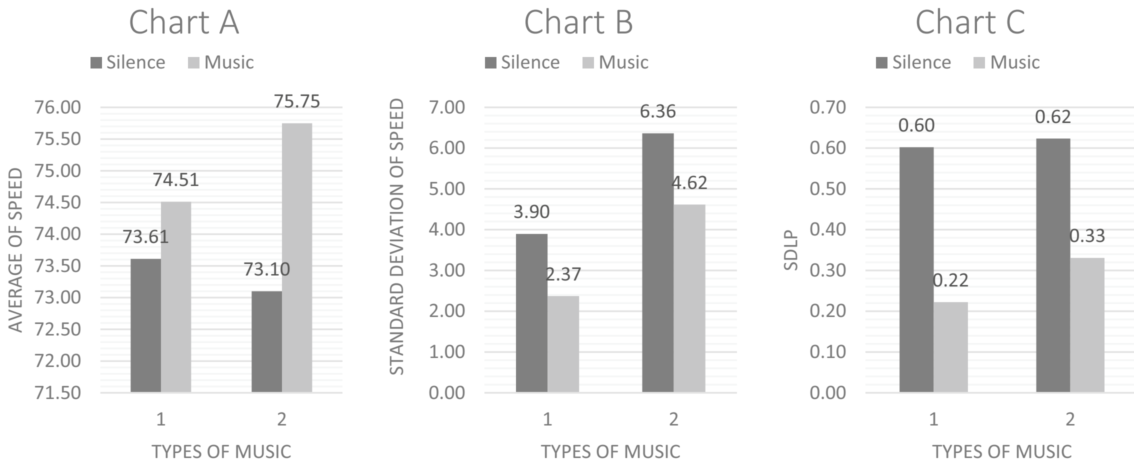

Fig. 2 Column diagram comparing simulator outputs in three modes of rest, silence and music in the experiment (group 1 is pop music and group 2 is classical music). Chart A shows the average speed, chart B shows the standard deviation of speed and chart C shows the standard deviation of lateral position (SDLP)

populations, including (1) driving with and without music, (2) driving while listening to classical music, and (3) driving while listening to pop music, were assessed using the MANOVA.[3] $P<0.05$ was taken as the level of statistical significance. In data analysis, the prerequisites for using ANOVA were met. Post hoc analysis test in the form of LSD multiple comparison test was performed for all of the variables which yielded a significant value of $P<0.05$, with a Bonferroni adjustment to 0.016 (0.05/3).

Results

The results of the functional scales

Figure 2 shows the changes in the mean speed, standard deviation of speed, and SDLP (standard deviation of lateral position) in the first 10 min of the test (t1, driving with no music), and driving with music (M, division of music by order). It can be seen that with both pop and classical music, the mean speed increases as the subject is listening to music, but the standard deviation of speed and standard deviation of lateral position (SDLP) decrease with music.

The significance of these results was assessed using the paired T test (Table 1), so that driving without music (t1) was taken as "before", and driving with music (M) as "after". No significant difference can be observed in the average speed between the before state and the after state, no matter which type of music is played. Meanwhile, SDLP reduced significantly with music ($P<0.05$). The standard deviation of speed also reduced significantly with classical music ($P=0.037$) and with pop music ($P=0.003$) compared to with no music.

After assessing the normality of the populations, we found that the mean speed population ($P=0.200$) and the standard deviation of speed ($P=0.159$) were normal, but standard deviation of lateral position (SDLP) population was not normal. The ANOVA was therefore used for the first two scales, which were normal, and the non-parametric Kruskal–Wallis test (H test) was used for the third scale. According to the ANOVA results, $P<0.005$ was observed for the mean speed ($F=0.246$, $P=0.783$) and the standard deviation of speed ($F=3.559$, $P=0.04$) between the groups. Given that this difference was significant for the standard deviation of speed, this difference was assessed in the groups in detail using the LSD post hoc test (Table 2). A significant difference was thus observed between the population driving without music and with classical music ($P=0.016$), indicating the reduction in SDLP with classical music compared to silence.

The results of the Kruskal–Wallis test for SDLP showed that Chi-squared = 23.374 and a significance level of Sig. <0.001. In other words, there is a minimum significant difference between the two groups. As shown in Table 3, there is a significant difference in SDLP in the two-by-two comparisons of the states (without music and with pop and classical music), and this value was reduced when music was played. Yet, no significant differences were observed between the pop and classical music in terms of this variable ($P=0.056$).

The results of the mental scales

Figure 3 shows the mean self-reported score of the KSS before the experiment (resting, t0), first 10 min of the

[3] Multivariate ANOVA.

Table 1 Paired *t* test results table of variables tested in both test days (classical and pop music)

Variable		Classical music			Pop music		
		Baseline/silence	Baseline/music	Silence/music	Baseline/silence	Baseline/music	Silence/music
Average of speed		–	–	−0.874 (P = 0.401)	–	–	−1.630 (P = 0.131)
Standard deviation of speed		–	–	**2.378 (P = 0.037)**	–	–	**3.838 (P = 0.003)**
SDLP		–	–	**14.504 (P < 0.01)**	–	–	**7.354 (P < 0.01)**
KSS		**−7.091 (P < 0.01)**	−1.505 (P = 0.161)	**2.303 (P = 0.042)**	**−4.926 (P < 0.01)**	**−4.000 (P < 0.01)**	**2.913 (P = 0.014)**
Average of heart rate		−0.009 (P = 0.993)	−1.395 (P = 0.191(	**−2.514 (P = 0.029)**	0.562 (P = 0.585)	−2.174 (P = 0.052(	**−3.435 (P = 0.006)**
Brain activity	(α + θ)/β	−1.078 (P = 0.304)	0.875 (P = 0.400)	**2.789 (P = 0.016)**	−2.193 (P = 0.051)	1.484 (P = 0.166)	**4.039 (P = 0.002)**
	α/β	1.336 (P = 0.208)	0.102 (P = 0.920)	**2.514 (P = 0.029)**	−1.999 (P = 0.071)	2.346 (P = 0.039)	**3.926 (P = 0.002)**
	(α + θ)/(α + β)	0.131 (P = 0.898)	0.813 (P = 0.434)	**3.553 (P = 0.005)**	−2.137 (P = 0.056)	−0.282 (P = 0.783)	**3.430 (P = 0.006)**
	θ/β	−0.313 (P = 0.760)	0.892 (P = 0.391)	**2.937 (P = 0.014)**	−2.119 (P = 0.058)	0.419 (P = 0.684)	**3.728 (P = 0.003)**

Table 2 ANOVA test results of three music conditions: (1) without music, (2) classical music and (3) pop music

Variables		Condition	Sig
Average of speed		Silence/pop	0.488
		Silence/classic	0.737
		Pop/classic	0.719
Standard deviation of speed		Silence/pop	0.586
		Silence/classic	**0.016**
		Pop/classic	0.055
Average of heart rate		Silence/pop	0.731
		Silence/classic	0.517
		Pop/classic	0.760
KSS		Silence/pop	0.219
		Silence/classic	0.109
		Pop/classic	0.698
Brain activity	(α + θ)/β	Silence/pop	**0.001**
		Silence/classic	0.027
		Pop/classic	0.181
	α/β	Silence/pop	**0.010**
		Silence/classic	0.031
		Pop/classic	0.631
	(α + θ)/(α + β)	Silence/pop	0.020
		Silence/classic	0.535
		Pop/classic	0.078
	θ/β	Silence/pop	**0.001**
		Silence/classic	0.103
		Pop/classic	0.075

Table 3 Kruskal–Wallis test results on the standard deviation of lateral position (SDLP)

Type of variable	Condition	Chi-Square	Sig
SDLP	Silence/pop	22.037	**0.000**
	Silence/classic	15.783	**0.000**
	Pop/classic	3.640	0.056

experiment (driving without music, t1), and driving with music (division of music by order, M). Figure 3 shows a relative increase in the KSS score when driving without music compared to the basal rate and a relative reduction in this scale when listening to music (both pop and classical) compared to without any music. Table 1 presents the results concerning the significance of these differences. According to participants' mental reports on the KSS, on the classical music day, the significance level was observed for the basal level vs. without music as well as for without music vs. with music. In other words, driving without music increased the KSS score and drowsiness. Moreover, the KSS score and drowsiness decreased with classical music compared to without any music, but no difference was observed between the basal rate and the 'with music' state, which means that drowsiness returned to its basal level with music. As for pop music, the statistical significance level was met in all three states. The assessments using the ANOVA showed no significant differences between the groups in the KSS score ($F = 1.147$, $P = 0.243$). The post hoc test showed no significant

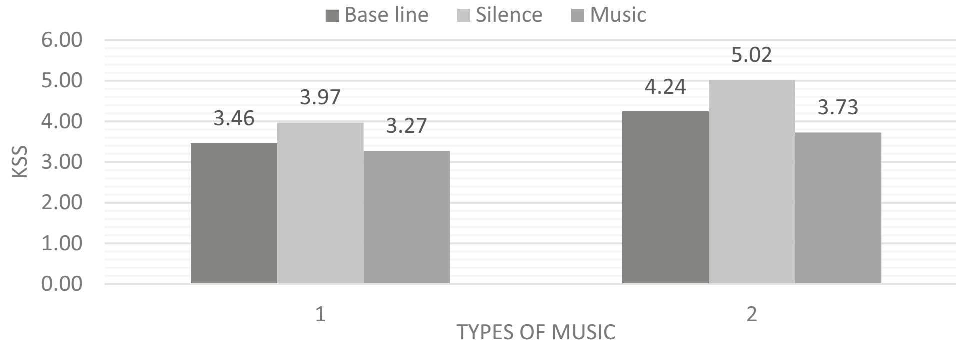

Fig. 3 Column diagram comparing KSS in three modes of rest, silence and music in the experiment (group 1 is pop music and group 2 is classical music)

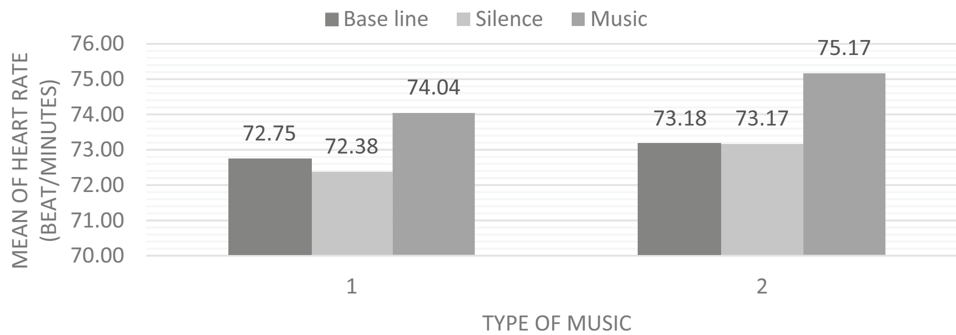

Fig. 4 Column diagram comparing average of heart rate in three modes of rest, silence and music in the experiment (group 1 is pop music and group 2 is classical music)

differences in the two-by-two comparisons of the three music populations in either of the three states (Table 2).

The results of the physiological scales

Similar to the KSS, Fig. 4 shows the variations in the mean heart rate in all the three states. As for the mean heart rate (Fig. 4), the basal and the 'no music' heart rate had approximately the same mean values on both the pop and classical music days; however, the mean heart rate increased with music compared to the basal and 'no music' heart rates. The results of the paired T test showed that no difference was observed between the basal rate and the rate without music or between the basal rate and the rate with music, regardless of the type of music played. The comparison of the states without music and with music showed a significant increase in the mean heart rate when either type of music was played. The ANOVA showed no significant differences between the groups in the mean heart rate ($F=0.215$, $P=0.808$). The post hoc test results also showed no significant differences (Table 1).

The changes in the last type of scale (the four brain wave algorithms) are presented in Fig. 5. In all the four algorithms and on both experiment days (pop and classical music), an increase can be observed in these ratios from the basal rate to the driving without music rate, and then another increase from the state of driving without music to driving with music.

Table 1 presents the results of the paired *T* test for these four scales. On the classical music day, a significant difference is observed between the silent and music states in all four algorithms ($P<0.005$), and the statistical significance level is $P=0.018$ for the first algorithm, $P=0.029$ for the second, $P=0.05$ for the third, and $P=0.014$ for the fourth algorithm. Just as the patterns observed on the classical music day, on the pop music day too, a significant difference was observed only when comparing the silent and music states in the first, third, and fourth algorithms ($P<0.05$). However, in the second algorithm, a significance difference was observed when comparing the rest and music ($P=0.039$) and the silent and music ($P=0.002$) states.

Finally, the ANOVA was carried out for the four brain algorithms in the three independent music populations (Table 2), and the results for the groups were ($F=6.912$, $P=0.003$) in the first pattern, ($F=4.281$, $P=0.022$) in the second, ($F=3.233$, $P=0.05$) in the third, and ($F=6.175$, 0.005) in the fourth pattern, and the difference was significant in all the four patterns ($P<0.05$). The post hoc test was used to find which groups contain this difference.

In algorithms 1 and 2, the significance level was between the two independent populations without music and with pop music ($P=0.001$) and without music and with classical music ($P=0.01$) in the second algorithm. The behavior in the third and fourth algorithms was almost the same, and a significant level was only observed when comparing the states without music and with pop music; therefore, ($P=0.001$) in the fourth algorithm.

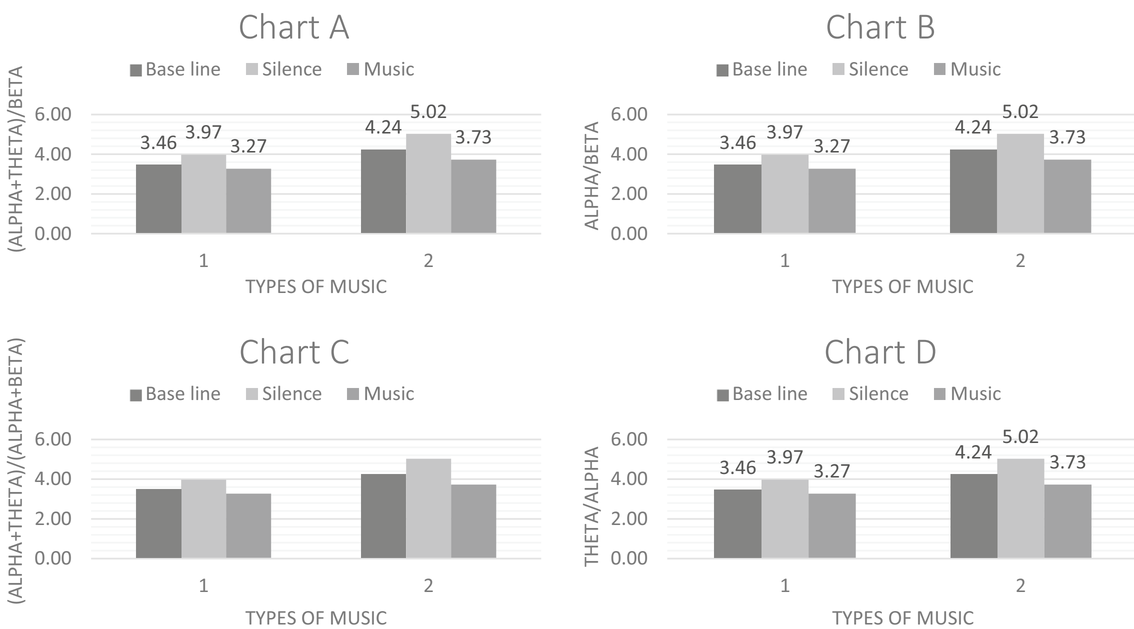

Fig. 5 Column diagram comparing four brain algorithm in three modes of rest, silence and music in the experiment (group 1 is pop music and group 2 is classical music). Chart A shows algorithm 1, chart B algorithm 2 and chart C shows algorithm 3 and chart D shows algorithm 4

Discussion

The present study was conducted to investigate the effect of Iranian classical and pop music on drowsiness during monotonous driving and while driving with little complexity. The main hypothesis of the study was that listening to high-tempo and loud music reduces drowsiness during driving, and this reduction is achieved by the increase in the mean heart rate and the reduction in the KSS score, mean speed, standard deviation of speed, SDLP, and the four brain patterns including (1) $(\theta + \alpha)/\beta$, (2) α/β, (3) $(\theta + \alpha)/(\alpha + \beta)$ and (4) θ/β.

In this study, a reduction was observed in the standard deviation of speed and SDLP when music was played (no matter which type, either classical or pop) compared to no music. The standard deviation of speed was higher on the pop music day ($P < 0.01$) than the classical music day ($P < 0.05$) compared to the no-music state. In another study [47] found a significant reduction in SDLP when listening to music. Research shows that drivers drive at a different speed when faced with a loud sound compared to silence [48]. This finding suggests that sound is indicative of a perception of speed during driving, while reduction in speed is recognized as one of the fundamental factors assisting in drowsiness detection systems [48]. In the present study, no difference was observed in the mean speed between the states with and without music. One of the reasons for these findings can be the fact that the participants were instructed to observe a driving speed of 70–90 km/h as much as possible.

According to the results obtained by [49], the effect of music on driving performance is somewhat dependent on the task assigned; e.g., no improvement is achieved in tasks such as chasing the front vehicle, which requires constant visual and motor engagement; nonetheless, it facilitates simple tasks. The task expected of the participants in our study was maintaining a speed of 70–90 km/h, maintaining the vehicle's lateral position in the middle lane of a three-lane highway with minimum traffic and driving in automatic transmission. Since the task assigned was simple and monotonous, the results concur with those of the cited study [49].

Given that a significant increase in the KSS score was observed over time in previous studies [50] investigating drowsiness during driving, this scale was used in the present study to assess the level of drowsiness. The KSS score reduced when either types of music were played. Previous studies [50] have shown that 5 min after the mean KSS reaches 8.5, drivers become reluctant to drive further. Yet, the mean KSS score was reported as 6.9 in drivers who succeeded to carry on driving and finish the experiment (with the duration of the experiment being 40 min) [51]. Notably, the results of our study showed that none of the drivers reached a KSS score above 7 when either types of music were played. The analyses of the three independent music populations showed that pop music had a greater effectiveness than classical music with regard to this scale.

Regarding heart rate, it can be argued that listening to music (classical or pop) generally leads to an increase in the mean heart rate. Although this increase could be attributed to the increase in the driver's alertness, it should be noted that a music-related increase in heart rate may depend on the range, speed and rhythm of the music [31]; that is, heart rate must have changed because of the rhythm and not drowsiness. Therefore, using the mean heart rate alone is not an accurate indicator of a driver's drowsiness and alertness, and relying on it alone will not suffice for this purpose.

The assessment of drowsiness through the biological scales, especially EEG, has always been a renowned method in many studies [52]. The four algorithms examined in the present study have also been previously examined in a study by [37], and in agreement with the present findings, the first of the four algorithms had the greatest tendency to increase [37] during drowsiness (Fig. 5). [46] also showed that since this combination (i.e., the first algorithm) is composed of the three main waves alpha, theta and beta, making the formula $(\alpha+\theta)/\beta$, it can provide a good indicator for differentiating between alertness and micro-sleeps. This algorithm reduced from the silent state to the music state, indicating reduced drowsiness with both types of music.

Similarly, [53] also conducted a study in 2006 to investigate the effect of pop music on drivers' drowsiness by monitoring biological scales (using algorithm two, i.e. α/β). Their results showed that fast high-tempo and loud music has the greatest effect in reducing this scale. In the present study, a significant reduction was observed in the other three algorithms from the silent state to the music state, but this reduction was less than that of algorithm one.

Another important point was that, in the first two algorithms, where the alpha and beta waves played a major role in changing the ratios, besides the comparison of silence and pop music, a significant difference and a reduction in drowsiness were also observed when comparing silence with classical music. Moreover, in the third and fourth algorithms, where theta and beta play a major role, the difference was significant only in the comparison of driving without music and driving with pop music, and this finding did not apply to classical music. According to a study by [54], changes in the alpha band comprise the most sensitive method for detecting drowsiness. One of the reasons for the significant difference in algorithms one and two compared to three and four is this higher sensitivity of the alpha waves (the main factor in algorithms one and two) compared to the other waves in detecting drowsiness. Generally, it can be inferred that, based on the brain waves' algorithms, pop music has had the greatest effect in reducing drowsiness, although no difference was observed between classical and pop music in the two-by-two comparisons of the classical and pop music populations in any of the above algorithms.

One of the objectives in this study was to create fatigue in the first 10 min of driving. To this end, a basal rhythm of the four brain wave patterns, the mean heart rate, and the KSS were recorded before beginning the experiment. Then, this rhythm was compared with the first 10 min of driving (the state without music), which showed an increase in the KSS score as a report of the mental perception of drowsiness. Nonetheless, the two types of music caused no difference in the mean heart rate and the four brain patterns. Since in most scales (EEG and the mean heart rate), no significant change was observed in the basal rate and the 'driving in silence' rate, we can conclude that the initial 10 min were not sufficient for causing drowsiness in the subjects. Future studies are recommended to allocate more time to this measure at the beginning of their experiments to cause drowsiness in their subjects.

The present findings confirm the hypothesis that playing high-tempo music affects driving performance and reduces drowsiness in the driver. In agreement with the present study, another study [55] conducted in real driving conditions showed that music affects the mental, functional, and physiological scales of drowsiness. The results of our study showed that both music had effect on drowsiness, but generally, compared to the basal and no-music states, pop music had a greater effect in reducing drowsiness and increasing alertness compared to classical music. It should be noted that most people listen to their favorite music while driving [56]. The taste in music has a significant role, such that listening to a music that is not liked can negatively affects the drivers' performance [57]. Given that pop music is very popular among the youth (i.e., the population of this study), it is not unreasonable that this music yielded better results.

In general, according to studies conducted on the results of cognitive function tests performed on the effects of short-term sleep deprivation (the night before the test) on driving, the greatest effect was observed on simple and sustained attention compared to other cognitive areas, such as reasoning [9]. Sustained attention is an important factor in studies on drowsiness during driving and should be taken seriously. One of the factors affecting sustained attention is the volume of traffic and the monotony of the road [48]. The ability to sustain attention over a long period is known as vigilance [58]. The main objective of this study was to play music to reduce monotony and thus create sustained attention and vigilance.

A limitation of this study was that the participants did not choose their type of music and its timing, because standardizing the methodology was crucial for the researchers. Further studies can adopt measures to overcome this limitation. Future studies are also recommended to recruit more general drivers instead of students to generalize these results. We also recommend to establish further studies in this field and differentiating them in age, driving license duration, and genre of music. Further studies are required in order to better understand why drowsiness indicators change in different directions when music is played.

Conclusion

Playing high-tempo music during driving can help to reduce drowsiness, change physiological responses, and driving performance. The best results can be accomplished when the driver actually likes the music played. Playing fast energetic music in the car is very helpful during high-risk hours. Playing these types of music on the radio or designing smart music selection systems can help achieve safer driving and improve drivers' performance and reduce their drowsiness.

Declarations

Conflict of interest The authors have no conflict of interest to declare.

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