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Effects of Self-Selected Music Tempo on Young Drivers' Speed and Acceleration

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This study examined the effects of participant-selected music on driving behavior using a driving simulator with 30 young male participants aged 20 to 25. Each participant drove under three conditions: no music, high-tempo music, and low-tempo music. Speed and acceleration data were recorded, and aggressive driving behavior was assessed via a questionnaire. Results showed that high-tempo music significantly increased average driving speed compared to no music, while low-tempo music had no effect. For speeds above 40 km/h (critical for pedestrian safety), both high- and low-tempo music influenced speed, with high-tempo increasing and low-tempo decreasing it. However, music type did not significantly affect maximum positive acceleration. Aggressive driving behavior, measured by questionnaire scores, showed no correlation with the impact of music on speed. The study also noted limitations in the simulator's ability to replicate braking sensations, leading to the exclusion of negative acceleration data. Statistical analyses (ANOVA and Tukey tests) confirmed significant differences in speed between high-tempo music and other conditions but no notable effects on acceleration or aggressive behavior. The findings suggest that music tempo can alter driving speed, particularly at higher velocities, but does not uniformly impact other driving metrics or aggression levels.

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1. Introduction

Studies have shown that listening to music while driving, as a secondary activity, may cause driver distraction. This has led to research aimed at identifying the extent to which different music genres influence driving behavior [1]. Multiple studies have indicated that listening to fast-paced, high-energy music results in faster driving and increased arousal among drivers while on the road [2]. It has been observed that loud music increases driving speed and the likelihood of running red lights during driving simulations [3]. Studies showed that driving behavior is influenced by the driver's perception of the road, surrounding environment, and hazardous situations [4]. Situations are considered potentially hazardous when a driver must alter speed or direction. Safer drivers tend to anticipate such situations in advance, applying braking or steering adjustments early to avoid collisions. Mental emotions are directly linked to physical responses; both negative and positive emotions exert distinct effects on the body's physical reactions [5]. Although music and podcasts are auditory stimuli, they create mental imagery in the listener's mind [6].

Babić et al. [7] showed that young male drivers, compared to other groups, pay more attention to road signs while listening to music. In contrast, Ünal et al. [8] found that listening to music reduces drivers' concentration during driving. In this study, drivers who did not listen to music demonstrated greater focus on the road. Widén and Erlandsson [9] examined the impact of music on youth risk-taking behavior, involving 9 women and 8 men. They found that music plays a significant role in shaping personal identity. Listening to loud music may lead to norm-breaking behaviors.

In a study involving 47 participants and two driving conditions − loud music and no music − drivers' heart rates were also measured. The results indicated that music enhanced drivers' focus when following the lead vehicle. The findings suggest that music

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does not disrupt steady following behavior; in fact, it may improve driver attention [10]. A study conducted by Farrell [11] on 20 college students found that loud music can impair driver reaction times. In another study, music was found to distract drivers and reduce the following distance between vehicles. Two music rhythms − soft and loud − were played for drivers, and results showed that loud music caused driver distraction and impaired control when approaching the vehicle ahead [12].

Wang et al. [13] demonstrated that listening to music while driving led to cognitive distraction and mental overload. Increased cognitive workload caused delays in response time to changes in traffic flow or unexpected braking. Music contributed to more frequent lane departures and rear-end collisions. Distraction is a significant factor in traffic accidents. Wang et al. examined two sources of distraction: listening to music and talking on the phone. A simulated brake light was used to measure reaction time in both scenarios. Drivers who were on the phone exhibited slower response times compared to those listening to music. Thus, drivers reacted faster while listening to music than while engaged in phone conversations.

Kasprzak [14] investigated how listening to music affects driver behavior. Participants were instructed to follow a vehicle, mimicking real-life driving behavior. The speed of the leading vehicle varied throughout the simulation, and drivers were expected to adjust their speed accordingly. Results showed that drivers listening to music exhibited better responses to speed increases or decreases of the lead vehicle. Another experiment by Niu et al. [15] showed that a mentally preoccupied driver performs worse in navigating the route. However, drivers who listened to music showed better vehicle-following behavior and steering control, though they also tended to be involved in more vehicle collisions.

Babić et al. [7] aimed to examine the impact of various selected music genres on the driving behavior and visual scanning patterns of young individuals in urban environments. The genres chosen by the drivers included classical, metal, and balkan folk music. Listening to each genre of music affected the frequency of drivers' glances at roadside signs.

A study compared driving performance while listening to music selected by the driver versus music selected by the researcher. The findings showed that young drivers listening to their preferred music in urban conditions drove at higher speeds than those who did not. Those listening to calm music exhibited more relaxed driving behavior [14].

Navarro et al. [16] utilized amateur drivers to investigate the effects of self-selected music on their driving behavior. When young and inexperienced drivers began driving while listening to their favorite music, the results indicated that such music generated positive energy, leading to improved driver responsiveness. In contrast, amateur drivers who drove without music experienced greater fear and anxiety while continuing along the route.

In a study, two types of music, selected by the experimenter and selected by the participant, were played for participants. Researchers used a driving simulator with two types of roads: one with simple conditions and low traffic volume, and the other an urban road with more challenging conditions and higher traffic. Results showed that music selected by the drivers had no significant impact on driving performance, while self-selected music improved overall driver performance. Listening to preferred music led to better lane maintenance and faster driving within legal speed limits. Drivers who listened to their own music also performed better when braking for pedestrians and stopping at red lights compared to those who listened to experimenter-selected music [17].

Ghojazadeh et al. [18] conducted research in which participants aged between 18 and 60 drove using a driving simulator. The first experimental condition involved listening to music (of any genre and format) chosen by the driver, while the second condition involved driving without music. The variables examined in this study included physiological indicators such as heart rate, breathing rate, and arousal level, as well as driver performance metrics like reaction time and delay ratio. The post-experiment results showed that listening to music had a positive effect on a driver’s ability to adjust the vehicle's position. However, loud music increased heart rate, which consequently led to more driver errors. Conversely, listening to calm, self-selected music resulted in smoother breathing and a more stable heart rate.

Music is one of the most popular activities while driving. Studies have shown mixed findings; some researchers concluded that music distracts drivers, while others found that preferred music improves driver comfort and performance in response to road obstacles. Whether music is selected by the experimenter or the participant can also influence driving behavior [19].

Most studies have focused on the general effects of music on driving behavior, while fewer have examined the differences between music chosen by the experimenter and that selected by the participant. In this research, only participant-selected music is used, and its differential impact on driving behavior is studied. The principal novelty of the present study, relative to prior research, can be classified into two primary categories. First, in previous investigations, the musical stimuli were selected by the experimenter; in contrast, the present study required participants to self-select their preferred music. This approach enhances the ecological validity of the findings, rendering them more representative of real-world driving conditions. Second, beyond the variables examined in earlier work − such as travel speed − the current study additionally incorporates an analysis of other driving maneuvers, namely lane-changing and car-following behavior. These maneuvers are inherently more complex and facilitate a more thorough and precise assessment of music's influence on driving performance.

The following section addresses data collection. Section three covers the data analysis methodology. Section four presents the discussion and conclusions. Finally, the study concludes with a summary of the findings.

2. Methodology

In this study, 30 young male students (between 20 and 25 years old) with more than 3 years of driving experience participated in a driving experiment using a K.N. Toosi University of Technology driving simulator, which has been used in many studies [20-

22] (Fig. 1). A fixed-base driving simulator was used for the experiments. The simulator can record measures accounting for vehicle locations, vehicle movement (e.g., speed, acceleration/deceleration), and driver operations (e.g., steering wheel angle). Given the inherent divergence between actual driving behavior and simulated settings, the validation of driving simulators is indispensable. The driving simulator, whose validity has been demonstrated in earlier studies and which has seen extensive prior use, was utilized in this investigation [23-25].

Fig. 1. Driving simulator.

Each participant drove in three simulated scenarios: without music, with high-tempo music, and with low-tempo music. In accordance with established protocols in driver behavior research, music with a tempo exceeding 120 BPM was classified as fast or high tempo, while music below 80 BPM was designated as slow or low tempo, with moderate tempo serving as the intermediate range. Music (genre and lyrics) was selected by participants. Each scenario lasted ten minutes, in addition to a warm-up period. The environment (urban) and traffic conditions (medium density) were identical for all scenarios. The sequence of driving scenarios was randomized. Specifically, following a warm-up drive and no-music driving, participants were randomly assigned to begin with either the high-tempo or the low-tempo music condition; the remaining music condition was then administered as the third scenario. This procedure was adopted to prevent potential confounding effects of fatigue or simulator adaptation on the experimental results.

The route was generally straight, with no appreciable horizontal curvature. Along the corridor, the level of service of the traffic was such that drivers experienced no congestion-induced speed reduction, thereby enabling them to maintain their desired operating speeds. Several intersections were located along the route to facilitate the collection of vehicular acceleration and deceleration data. The length of the route was determined as a function of the drivers' average travel speed. The posted speed was 90 km/hr.

Speed and acceleration data were collected for each driver across the scenarios. Due to the small number of participants in other age and gender groups, their data were excluded from analysis. This exclusion helped eliminate the effects of other variables, allowing the study to focus solely on the influence of music.

In addition to the driving data, participants also completed an Aggressive Driving Behavior Questionnaire (ADBQ) to measure aggressive behavior. The ADBQ is a 20-item self-report instrument to assess drivers' propensity for engaging in aggressive driving behaviors. The questionnaire was developed using a factor-analytic approach that combined five previously established aggressive driving scales [26]. Participants rate each item on a 6-point Likert-type scale ranging from 1 (Never) to 6 (Nearly All the Time). The instrument has demonstrated robust psychometric properties in previous studies, with high internal consistency (Cronbach's α = 0.77 to 0.86) and established predictive validity in both simulated and real-world driving contexts [26]. For the present sample, the ADBQ yielded a Cronbach's alpha of 0.85, indicating acceptable internal consistency.

After collecting the data from participants, the dataset was divided into two categories: speed data and acceleration data. These data were analyzed from several perspectives. Initially, the average driving speed of participants in different scenarios was examined, followed by the analysis of acceleration. Additionally, the relationship between participants' aggressive behavior and the effect of music type on average speed was evaluated. Descriptive and inferential statistics were used for this purpose. Given that there were three different data groups or scenarios, two statistical tests (ANOVA and Tukey) were applied. ANOVA served as a preliminary test to explore whether significant differences existed among the scenario data. Subsequently, the Tukey test was employed to determine the nature and direction of those differences across scenarios. Since the data were analyzed in an aggregated (cumulative) manner, analysis of variance (ANOVA) was employed.

3. Results and discussion

In this section, the speed data, acceleration data, and the results of the aggressive behavior questionnaire are analyzed with respect to the type of music played during driving.

3.1. Speed

Fig. 2 presents a sample speed-time graph for a participant under different driving scenarios. In this graph, speed is represented in three colors: yellow indicates driving with low-tempo music, green indicates driving without music, and red indicates driving with high-tempo music. The horizontal axis shows the 600-second driving period for each participant, while the vertical axis indicates the driver's speed in kilometers per hour. Speed data were recorded at intervals of 0.1 seconds.

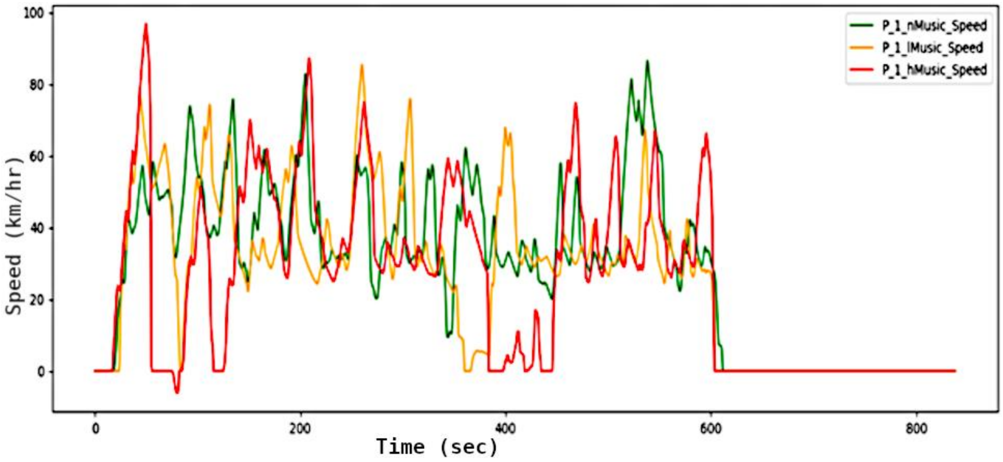

Fig. 2. Speed-time chart of a sample driver in three scenarios.

Fig. 3 illustrates the average speed of each driver across the different driving scenarios.

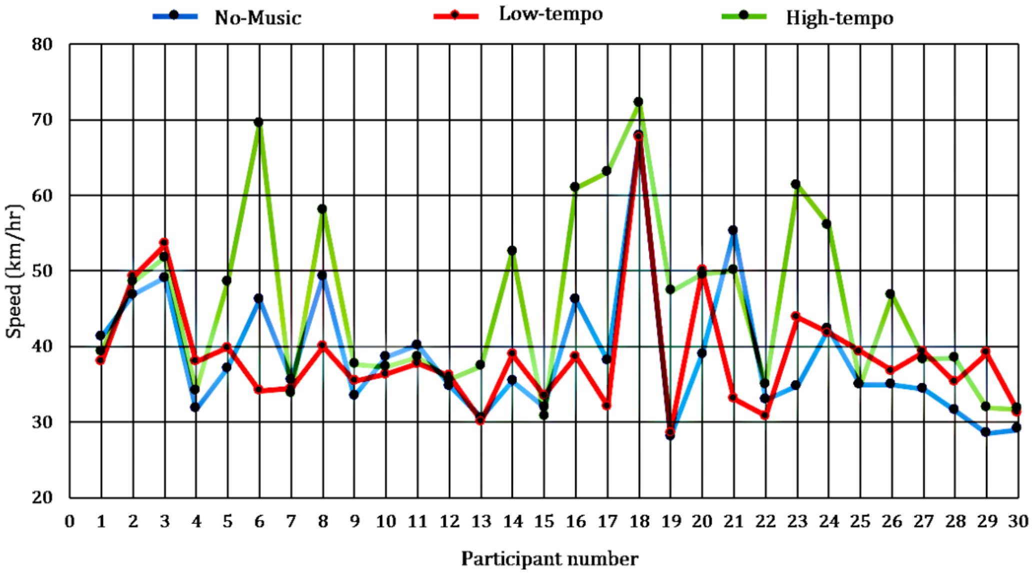

Fig. 3. Average driving speed of drivers.

Table 1 presents the results of the ANOVA test conducted on all average speed data.

Table 1. ANOVA test of average speeds in different scenarios.

Statistics	Significant level of variance analysis test (one-way ANOVA)
5.23	0.007

The ANOVA p-value was less than 0.05, indicating a statistically significant difference among the three groups of data. It is worth noting that, for deeper analysis, ANOVA was also performed individually for each participant's data. Approximately 90% of cases revealed significant differences among their scenario groups, confirming the overall ANOVA findings. To rank the average speeds across scenarios, the Tukey post hoc test was used, and its results are presented in Table 2. Pairwise comparisons using Tukey's test showed that the average speed under the high-tempo music condition differed significantly from both the no music and low-tempo music conditions. However, there was no significant difference between the no music and low-tempo music conditions. Similar results have been reported in previous studies. Brodsky demonstrated that drivers exposed to fast-paced music not only drove faster but also committed more traffic violations [27, 28].

Table 2. Comparing the average speed in different scenarios.

Tukey's HSD pairwise group comparisons (95.0% confidence interval)					
Comparison	P-value	Comparison	P-value	Comparison	P-value
(No music - low tempo music)	0.999	(Low tempo music - high tempo music)	0.018	(No music - high tempo music)	0.016

The relationship between speed and crash risk is well-established as exponential: even small increases in mean speed lead to disproportionately large rises in severe and fatal crash involvement [29, 30].

3.2. Speeds above 40 km/h

Given the role of speed in the severity of accidents, the effect of music type on speeds above 40 km/h was examined. According to a study [31], in vehicle-pedestrian collisions, the risk of fatality is less than 10% when the vehicle speed is below 40 km/h. On the other hand, given that the traffic volume was low, vehicles are not expected to have selected speeds below 40 km/h. Speeds lower than 40 km/h were predominantly associated with the periods immediately before and after a stop. Therefore, one-way ANOVA analysis was conducted again using only speed data above 40 km/h. Speeds below 40 km/h were excluded, and averages were calculated based on the remaining data. The null hypothesis was that the average speeds across the three conditions (no music, low-tempo music, and high-tempo music) were equal. Based on the findings, the null hypothesis was rejected in 97% of cases, clearly indicating that music playback significantly influenced driver behavior. In other words, high-tempo music increased average speed, while low-tempo music reduced it, compared to the no music condition (Table 3).

Table 3. Comparing the average speed in different scenarios.

Tukey's HSD pairwise group comparisons (95.0% confidence interval)					
Comparison	**P-value**	**Comparison**	**P-value**	**Comparison**	**P-value**
(No music - low tempo music)	0.046	(Low tempo music - high tempo music)	0.038	(No music - high tempo music)	0.009

3.3. Acceleration

Acceleration reflects the rate of change in speed over time. Therefore, the selected time interval directly influences the calculated acceleration value. If the time interval is too long, the speed changes within that window may be smoothed out, with only the initial and final speeds considered, which potentially causes error in the analysis. On the other hand, selecting intervals that are too short may impose unnecessary computational load on the model. Thus, acceleration was calculated using various time intervals and the results analyzed. It was observed that when the time interval was less than one second, despite a significant increase in computational complexity, no meaningful additional detail was captured. Hence, it was deemed reasonable not to use intervals shorter than one second. Conversely, when the interval exceeded three seconds, important fluctuations in acceleration were smoothed out and excluded from the analysis. Therefore, a one-second interval was identified as the optimal time frame for calculating acceleration.

Maximum and minimum accelerations were calculated. Negative acceleration indicates deceleration or braking. It was observed that the values of negative acceleration differed significantly from those of positive acceleration. This discrepancy may be attributed to the driving simulator's limited ability to convey deceleration, particularly in modeling braking force. This is a limitation of the simulator, which cannot effectively replicate the physical sensation of braking. Therefore, negative acceleration data were excluded from further analysis. Some studies demonstrated that drivers brake more abruptly and more strongly than in real driving because finding safety margins is more difficult in a driving simulator than in the real world [28, 32]. Fig. 4 displays the maximum positive acceleration for each driver. It should be noted that acceleration is typically zero and only occurs when the driver actively changes speed; hence, averaging acceleration values would be meaningless and would result in values close to zero. To determine maximum acceleration, the five highest acceleration values for each participant were averaged. Fig. 4 displays the maximum positive acceleration for each driver in different scenarios.

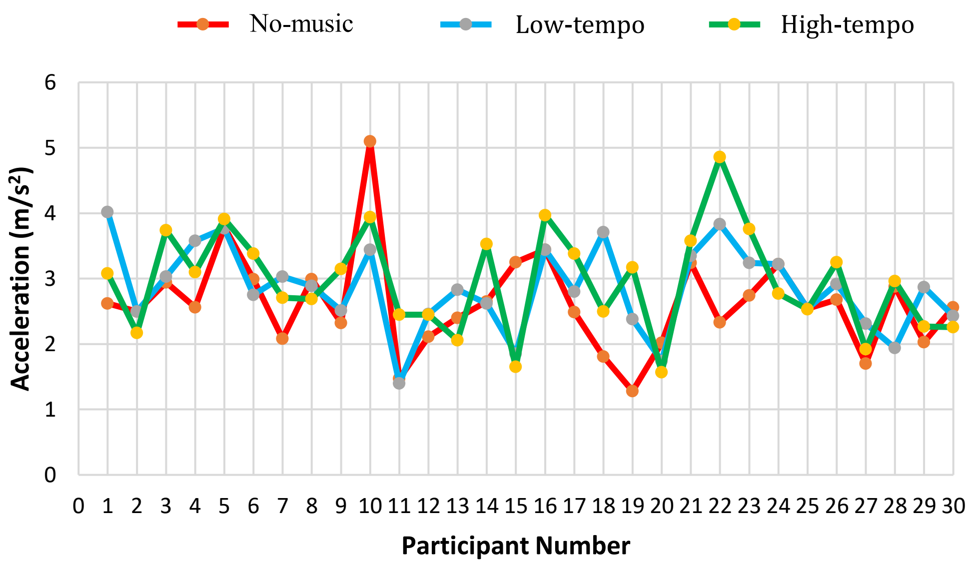

Fig. 4. Maximum acceleration during driving.

Fig. 5 and Tables 4 and 5 show the results of ANOVA and Tukey tests on the maximum positive acceleration data. The significance level criterion value was greater than 0.05, and the null hypothesis (that the means of the three groups, namely maximum acceleration under no music, low-tempo music, and high-tempo music conditions, are equal) was not rejected. Therefore, playing music does not have a significant effect on the drivers' maximum positive acceleration. The Tukey pairwise comparison test also indicates that the null hypothesis was not rejected in any of the pairwise comparisons, meaning there were no significant differences between the group means in any two-group comparisons. In other words, music did not affect the drivers' maximum positive acceleration. Niu et al. [33] reported that high-tempo music significantly increased the standard deviation of longitudinal acceleration, reflecting more volatile and aggressive control of the vehicle.

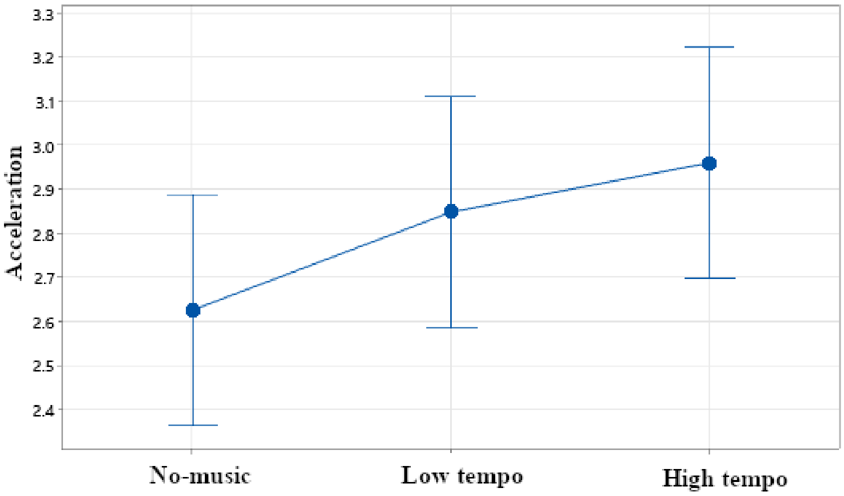

Fig. 5. Interval plot of accelerated maximization data for different scenarios.

Table 4. ANOVA of accelerated maximization data for different scenarios.

Source	DF	Adj SS	Adj MS	F-value	P-value
Factor	2	1.738	0.8688	1.67	0.195
Error	87	45.321	0.5209		
Total	89	47.059			

Table 5. Tukey simultaneous tests for differences of means.

Difference of levels	Difference of means	SE of difference	95% CI	T-value	Adjusted p-value
No music - low tempo music	0.222	0.186	(−0.222, 0.666)	1.19	0.461
No music - high tempo music	0.334	0.186	(−0.110, 0.778)	1.79	0.178
Low tempo music - high tempo music	0.112	0.186	(−0.332, 0.556)	0.60	0.820

3.4. Aggressive behavior and speed variations in scenarios

In the data collection section, it was stated that the participants completed the aggressive behavior assessment questionnaire before starting the test. Participants expressed their opinions on a scale of very low, low, moderate, high, and very high, where the "very high" option indicated the highest level of aggressive behavior and the "very low" option indicated the lowest level of aggressive behavior in response to the given question. The qualitative responses of the participants were converted into numerical scores ranging from 1 (very low) to 5 (very high). As the questionnaire score increased, the participant's behavior was estimated to be more aggressive. The maximum and minimum scores of the aggressive behavior assessment questionnaire were 115 and 23, respectively. Fig. 6 displays the distribution of participants' aggressive driving behavior scores.

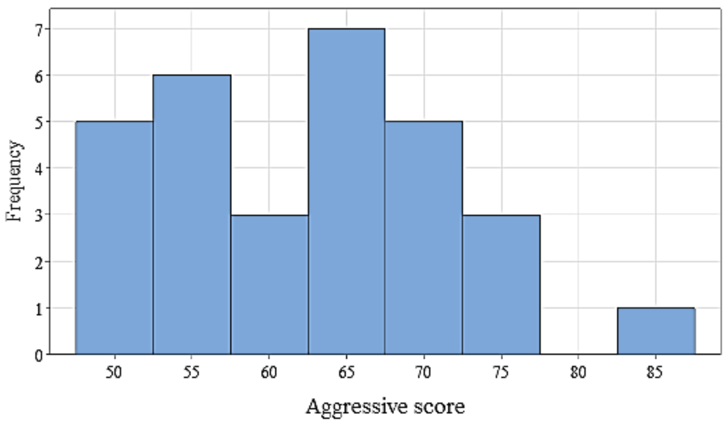

Fig. 6. Participants' aggressive driving behavior scores.

The relationship between drivers' aggressive behavior and the effect of low-tempo and high-tempo music was examined using the Pearson correlation test. The effect of low-tempo music was defined as the difference in mean speed between the no music condition and the low-tempo music condition, while the effect of high-tempo music was defined as the difference in mean speed between the no music condition and the fast music condition. It was observed that there was no significant relationship between aggressive behavior and the effect of music type on the participants' mean speed (Table 6). Similar results to those of Brodsky's study have been obtained [3, 27]. The aggressive driving questionnaire is designed to assess stable aggressive driving traits, whereas music can temporarily alter arousal and mood. This distinction between trait and state responses should be studied in future studies.

Table 6. Pairwise Pearson Correlations between the difference in average speed of different scenarios and the aggressive scale.

Sample 1	Sample 2	Correlation	95% CI for ρ	P-value
Difference between no music and low tempo	Aggressiveness	−0.360	(−0.638, 0.000)	0.051
Difference between high tempo and no music	Aggressiveness	0.321	(−0.045, 0.610)	0.084
Difference between high tempo and no music	Difference between no music and low tempo	−0.026	(−0.382, 0.338)	0.893

3.5. Limitations and future work

It is worth noting that the majority of university students are young adults; consequently, the study sample consisted primarily of young university students. Furthermore, when drivers are required to operate a driving simulator while simultaneously adhering to specific conditions (e.g., listening to music), recruiting a large number of participants and volunteers becomes particularly challenging. In this study, a minimum of 30 participants were recruited to enable the use of parametric tests and to enhance the statistical significance of the results. This number of participants is consistent with prior studies in which 30 or fewer participants were recruited for driving tests [34-37]. This demographic homogeneity and number of participants represent a limitation of the current research, which could be addressed in future studies.

As previously mentioned, driving simulators inherently differ from real-world driving conditions in unavoidable respects. Consequently, the current investigation could be further validated or replicated through on-road driving tests. One of the key limitations of driving simulators is the overestimation of deceleration, which can be corrected or calibrated through real-world experiments in future work. This research has not considered driver-level variables such as annual mileage, prior simulator experience, fatigue, mood, and risk-taking tendency, which may influence driving behavior and could influence the experimental outcomes.

Although tempo and loudness were controlled in this study, given that the aim was to examine the effect of drivers' preferred music, factors such as emotional intensity, arousal level, genre, and lyrics were not controlled, which could be investigated in future research.

This paper has focused on the average speed, speed above 40 km/h, and maximum positive acceleration. Additional measures such as speed variability, lane keeping, headway, time-to-collision, braking frequency, and lateral deviation can be studied in future work.

4. Conclusions

Music can influence human moods and emotions. While driving, listening to different types of music may have varying effects on the driver and influence their driving behavior. This study investigated the effect of music type on drivers' speed and acceleration. Participants took part in three driving scenarios: without music, with high-tempo music, and with low-tempo music in a driving simulator, and their driving data were collected. The music was selected by the drivers themselves to ensure familiarity and better simulation of driving conditions. Furthermore, to study the relationship between music and aggressive driving behavior, participants completed an aggressive behavior assessment questionnaire.

The main findings of this study are summarized as follows:

- It was observed that fast-tempo music increased the average driving speed compared to the no music condition, whereas slow-tempo music had no effect on the participants' average speed.
- Considering that speeds over 40 km/h can cause harm to pedestrians, average speeds above 40 km/h were also examined. In this context, it was found that both slow-tempo and fast-tempo music significantly influenced participants' average speeds, causing a decrease and increase in speed, respectively.
- No significant relationship was found between drivers' maximum positive acceleration and the type of music. Moreover, no significant relationship was observed between drivers' aggressive behavior and music type. In other words, increased aggressive behavior did not amplify the effect of music.

Statements & declarations

Author contributions

Aref Ansari: Data curation, Investigation.

Ehsan Ramezani-Khansari: Supervision, Writing - Original Draft, Visualization, Software.

Ali Abdi Kordani: Writing - Review & Editing, Formal analysis.

Hamid Mirzahossein: Validation, Methodology.

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Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

The authors declare that they have no competing interests.

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