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Corresponding Author:	Jordan Navarro Universite de Lyon Bron, FRANCE
Corresponding Author's Institution:	Universite de Lyon
Corresponding Author E-Mail:	jordan.navarro@univ-lyon2.fr
Order of Authors:	Jordan Navarro
	François Osiurak
	Vivien Gaujoux
	Emanuelle Reynaud
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TITLE:

Driving Under the Influence: How Music Listening Affects Driving Behaviors

AUTHORS AND AFFILIATIONS:

Jordan Navarro[1,2], François Osiurak[1,2], Vivien Gaujoux[1], Marie Claude Ouimet[3], Emanuelle Reynaud[1]

[1]Laboratoire d'Etude des Mécanismes Cognitifs (EA 3082), University Lyon 2, Paris, France
[2]Institut Universitaire de France, Paris, France
[3]Faculté de médecine et des sciences de la santé, Université de Sherbrooke, Longueuil, Canada

Corresponding author:
Jordan Navarro (Jordan.Navarro@univ-lyon2.fr)

Email addresses of co-authors**:**
François Osiurak (Francois.Osiurak@univ-lyon2.fr)
Vivien Gaujoux (Vivien.Gaujoux@univ-lyon2.fr)
Marie Claude Ouimet (Marie.Claude.Ouimet@USherbrooke.ca)
Emanuelle Reynaud (Emanuelle.Reynaud@univ-lyon2.fr)

KEYWORDS:
music, tempo, driving behaviors, driving simulation, car-following task, speed control, level of arousal, mood

SUMMARY:
Here, we present a protocol to assess driving behaviors while following a vehicle in a simulated driving environment. The presented protocol is used to compare the impact of different auditory backgrounds on driving behaviors.

ABSTRACT:
Car driving is a daily activity for many individuals in modern societies. Drivers often listen to music while driving. The method presented here investigates how listening to music influences driving behaviors. A driving simulation was selected because it offers both a well-controlled environment and a good level of ecological validity. Driving behaviors were assessed through a car-following task. In practice, participants were instructed to follow a lead vehicle as they would do in real life. The lead vehicle speed changed over time requiring constant speed adjustments for the participants. The inter-vehicular time was used to assess driving behaviors. To complement the driving behaviors, the subjective mood and physiological level of arousal were also collected. As such, the results collected using this method offer insights on both the human internal state (i.e., subjective mood and physiological arousal) and driving behaviors in the car following task.

INTRODUCTION:
Car driving activity has increased quickly over the last decades and is now a daily activity for many individuals in modern societies. In line with this growth, car-driving activity has become a hot

topic of investigation for the human factor community[1].

There is an extremely limited number of major cultural activities that typically define humankind regardless of the population and the period of history considered[2]. Music is one of these activities along with tool use and symbolic reasoning underpinning language abilities[3]. Playing and listening to music is therefore a crucial individual and social activity. Based on an exhaustive literature review, Schäfer et al.[4] found about 130 different non-redundant functions associated to music listening and three music listening meta-functions were then identified: (1) arousal and mood regulation, (2) self-awareness achievement, and (3) social relatedness expression. As a consequence, people are frequently listening to music in a variety of situations and locations[5]. Among those situations, listening to music while driving is extremely common with drivers reporting listening to music during about three quarters of their driving time[6].

Music listening is known to impact the listener’s emotional state[7] and thus to induce mood changes in a variety of situations and research areas[8]. According to the mood congruency theory, a person’s behavior is related to his/her mood[9] with evidence gained from both neuroimaging[10] and behavioral experiments[11]. Following this rationale, music listening can change drivers’ mood, which in turn can change driving behaviors.

Musically-induced mood changes while driving were found to result in performance improvements under certain conditions or impairments under other conditions. On the one hand, in complex and highly demanding driving environments, calm music was found to mitigate affective states: it has a softening effect on negative emotions, reduces the level of stress, and improves driver’s relaxation and calm[12]. This relaxing effect was reported to be more efficient when using abrupt music changes compared to gradual music changes[13]. On the other hand, people were slower to detect hazards in driving scenes when anger was previously induced through music and guided imagery compared with neutral mood performances[14]. Happy music listening while driving was also found to be detrimental to lateral control efficiency, while sad music had no significant effect on lateral control of the vehicle[15]. In brief, drivers’ mood can impact driving performances in opposite ways depending on the music and associated mood induction and on the driving situation considered.

The purpose of the method reported here is to offer an experimentally well-controlled driving situation to investigate the impact of music listening on driving behaviors. To ensure the reproducibility of the driving situation, a method based on driving simulation has been implemented. At the first glance, a driving simulation might be considered as a degraded version of real driving investigations. However, the reality is more complex, and a given experimental setup cannot be considered as the best experimental solution in absolute terms. Rather the best experimental setup is the one that suits the most accurately the needs of the investigation concerned[16]. If real car-driving is the experimental setup that best reproduces the everyday life driving situations, it also comes with some drawbacks: driver safety in case of experimental manipulations, potential impairments in terms of driving performances, and difficulties in the control of the driving environment, including traffic, weather conditions, light conditions, level of ambient noise, etc. Conversely, if driving simulators are not as realistic as real vehicles, experimental conditions and manipulations can be strictly controlled and replicated[17]. As a result, different participants can be exposed to the exact same experimental conditions. In addition, experimental manipulations potentially impairing driving performances are made possible as only virtual safety (and not real safety) is engaged. Altogether, a driving simulation offers an excellent compromise between the need to conserve the driving activity natural (i.e., external validity) and the need for a strong experimental control (i.e., internal validity).

PROTOCOL:

All methods described here have been approved by the Ethics Committee of the Department of Psychology of University Lyon 2 and informed consent was obtained from all participants.

NOTE: Participants were recruited by means of notices posted in the local community and at the University.

1. Participants

1.1. Ensure that participants have a driving license and at least two years of driving experience.

1.2. Ensure that participants have normal or corrected to normal vision and audition.

1.3. Ensure that participants do not suffer from a mental illness (e.g., schizophrenia).

1.4. Recruit a similar number of females and males.

1.5. Equip participants with a heart rate belt linked to a watch to monitor heart rate.

1.6. Ask participants to choose freely their own preferred music track (examples of participants choice: Uptown Funk by Mark Ronson featuring Bruno Mars or Cheerleader by OMI). Ask participants to provide that music track on a USB stick. Use this track to create different musical backgrounds for the experiment (see section 3).

2. Driving simulation

NOTE: The following steps are described based on a new driving simulator, a BB_Sim developed at the Université de Sherbrooke, which includes one computer, three screens, as well as a steering wheel and acceleration and braking pedals for driving controls. The initial study was conducted with a different driving simulator using the open-source OpenSD2S software[18].

2.1. Set the driving simulation driving noise (i.e., engine of the driven vehicle) at ± 25dB.

2.2. Seat the participant in front of the simulator, approximately 60 cm from the screens (three screens located in front of the participant, 48 cm x 30 cm each, covering a total of 137.52° of the visual angle on the horizontal axis and 28.65° of the visual angle on the vertical axis), in a modified car seat.

2.3. Let the participant adjust the distance between the seat and the pedals with the handle underneath the seat.

2.4. Once the participant is comfortably positioned, provide instructions on using the features of the simulator (i.e., how to interact with the acceleration and braking pedals and the steering wheel).

2.5. Inform the participant about simulation sickness that can sometimes occur, and let the participant know that the simulation will be stopped at any time if necessary.

2.6. Use a rural roadway with one traffic lane per direction with five left bends and five right bends and without any traffic.

3. Musical background

3.1. Use software to modify the tempo of the music, without any pitch modification.

3.2. Create four auditory backgrounds for each participant: (1) No Music, with no additional music played; (2) Music, each participant preferred music track without modification; (3) Music +10, each participant preferred music track with an increased tempo. The tempo is increased by 10 % of the regular tempo; (4) Music-10, each participant preferred music track with a decreased tempo. The tempo is decreased by 10 % of the regular tempo.

3.3. Control the intensity of the music. Music intensity is known to modify driving performances[19]. Set the intensity to 75 dB for all auditory backgrounds but the No Music condition.

3.4. Use a software to play one of the four musical backgrounds for the entire duration of each drive. Play the music on two lateral powered monitor speakers located on the right and on the left of the participant.

4. Simulated car-following task

4.1. Provide instructions concerning the task: "Drive as you would do in a real-life situation. Your goal is to follow the vehicle in front of you at a close but safe constant distance, as if following a friend on an unknown route." Inform the participant that there is no traffic or obstacles on the path.

4.2. Start the simulation with a training phase in order to familiarize the participant with the driving simulator, the simulated environment, the vehicle controls, and the car-following task. When the participant feels comfortable, stop the training phase.

4.3. Proceed with the experimental drives. Launch the simulated car-following task and one of the four musical backgrounds.

4.4. Start recording the heart rate data at the beginning of each simulated car-following task and end it at the end of that driving task.

4.5. For the simulated car driving task, have the driver first drive for 50 m before stopping at a “Stop” sign. Once the participant’s vehicle has stopped, a leading vehicle appears on the road at the left of the intersection. Instruct the participant to follow the vehicle. After an initial phase in which the speed of the leading vehicle is stationary and set at 20 kph allowing the driven vehicle to catch up, its speed then varies sinusoidally between 45 kph and 70 kph within each period of 60 s for a total of 3 min. Then, ask the participant to stop driving.

4.6. For the car-following task, use a two-lane road with opposite traffic directions. In order to provide a realistic driving environment, use a road section with a balanced number of left (n = 5) and right bends (n = 5) with various radii of curvature from 45 m to 300 m. Additionally, add visual elements on the edges of the road section such as trees, barriers, fields, and landform.

4.7. Repeat the car-following task for each of the four musical backgrounds. The car-following task takes about 4 min (3 min of actual car-following plus the beginning and ending of the driving simulation).

NOTE: The duration of the car-following task can be extended if required.

4.8. Take a 5 min break between each car-following task to reduce carryover effects.

4.9. Counterbalance the order of presentation of the four musical backgrounds between participants using a Latin square design.

5. Data collection

5.1. Collect the participants’ subjective mood after each condition using the Brief Mood Introspection Scale (BMIS)[20] validated in French[21,22]. This questionnaire provides data on participants’ mood on four mood dimensions: pleasant/unpleasant, arousal/calm, positive/tired, and negative/relaxed.

5.2. Collect physiological measures. Compute the mean heart rate and heart rate variability over the entire drive for each experimental condition using the data recorded by the heart rate monitoring watch at a sample per second. In practice, compute mean heart rate by averaging all the data collected during each experimental condition and heart rate variability by calculating the standard deviation on the same data.

5.3. Measure objective driving behaviors through the mean inter-vehicular time and the inter-vehicular time variability. Record both driven and leading vehicle position and speed at each time step at a sample rate of 60 Hz.

5.3.1. At each time step, compute the inter-vehicular time as the time required for the driven vehicle to reach the position of the lead vehicle if the position of the lead vehicle was frozen and the speed of the driven vehicle was constant.

5.3.2. Average all the values collected for a drive to obtain the mean inter-vehicular time and compute the standard deviation on those values to obtain the inter-vehicular time variability.

NOTE: Several variables can be computed to qualify driving behaviors during a car-following task. The inter-vehicular time is particularly well-suited as it offers an indication of the safety margin between the driven vehicle and the lead vehicle chosen by the driver.

REPRESENTATIVE RESULTS

The main comparisons are based on the following experimental conditions. The first experimental condition is No Music versus Music, a comparison between the No Music background and the individual preferred Music background using a pairwise *t*-test. These analyses were meant to assess the influence of listening to preferred music compared to a control condition without music. The second experimental condition is four different musical backgrounds, a comparison between No Music, Music, Music +10 and Music -10 corresponding to a music tempo manipulation compared to a control condition without music, using repeated measures ANOVAs.

As compared with No Music, Music had a significant effect on subjective mood as observed on three of the four dimensions of the Brief Mood Introspection Scale (**Figure 1**). Significant differences were found for the pleasant-unpleasant ($t(23) = -2.75$; $p < 0.01$), arousal-calm ($t(23) = -2.67$; $p < 0.01$), and positive-tired ($t(23) = 3.54$; $p < 0.001$) dimensions. No significant differences were observed for the negative-relaxed dimension ($t(23) = 1.05$; $p = 0.153$).

[Place Figure 1 here]

Considering all four auditory backgrounds, a significant effect on subjective mood was observed on the four dimensions of the BMIS (**Figure 2**). Significant differences were found for the pleasant-unpleasant ($F(3,69) = 2.75$; $p < 0.05$), arousal-calm ($F(3,69) = 7.74$; $p < 0.001$), positive-tired ($F(3,69) = 7.36$; $p < 0.001$), and negative-relaxed ($F(3,69) = 3.24$; $p < 0.03$) dimensions.

[Place Figure 2 here]

The mean heart rate was significantly different for the No Music and Music backgrounds ($t(18) = -5.05$; $p < 0.001$; **Figure 3**). The heart rate variability was not significantly impacted by the background condition ($t(18) = -1.58$; $p = 0.07$; **Figure 3**).

[Place Figure 3 here]

The mean heart rate was significantly different under the four auditory background conditions

($F(3,51) = 4.25$; $p < 0.01$; **Figure 4**). The heart rate variability was not significantly impacted by the background condition ($F(3,51) = .94$; $p = 0.43$; **Figure 4**).

[Place Figure 4 here]

The mean inter-vehicular time was significantly different for the No Music and Music backgrounds ($t(23) = 2.53$; $p < 0.01$; **Figure 5**). The standard deviation of the inter-vehicular time was not significantly impacted by the background condition ($t(23) = -0.11$; $p = 0.55$; **Figure 5**).

[Place Figure 5 here]

The mean inter-vehicular time was not significantly different under the four auditory background conditions ($F(3,69) = 1.88$; $p = 0.14$; **Figure 6**). Similarly, the standard deviation of the inter-vehicular time was not significantly impacted by the background condition ($F(3,69) = 1.57$; $p = 0.20$; **Figure 6**).

[Place Figure 6 here]

Listening to music or not (No Music versus Music conditions) while driving was found to have a significant effect on subjective mood, physiological level of arousal, and driving performances. In more detail, listening to favorite music behind the wheel was found to impact positively on the mood, leading to a higher level of pleasantness, arousal, and a more positive mood (**Figure 1**). The comparison between no music and music backgrounds revealed a significant influence of music listening on drivers' mean heart rate. Music increased the mean heart rate. In line with subjective data, this increase can be interpreted as an increase in arousal induced by music listening (**Figure 3**). It is assumed that the increase of arousal produced by music listening translates into driving behavior modifications. In the car-following task, drivers had a smaller inter-vehicular time while listening to music compared with the control condition without music to listen (**Figure 5**). This can be interpreted as a reduction of drivers' safety margin with the vehicle to follow in an external assessment perspective (i.e., absolute safety margin). However, from the drivers' perspective, the inter-vehicular time reduction is most probably adjusted depending on their own perceived abilities. With a higher level of arousal, faster detections and responses to follow the speed changes of the leading vehicle can be made. Still from drivers' perspective, a reduction of the inter-vehicular time is required to maintain the same safety margin (i.e., relative safety margin). In sum, the experimental protocol reported here was found to be sensitive enough to reveal mood changes, physiological changes, and driving behavior changes for the comparison between no music and music conditions. The manipulation of the music tempo (i.e., comparison of four different auditory backgrounds) did not translate into the same pattern of results. If all four dimensions of subjective mood and physiologically assessed arousal were found to be significantly influenced by the auditory background, no clear impact of the music tempo was found. Indeed, music, music +10 and music -10 conditions had an insignificantly different effect on drivers' subjective mood and physiological arousal (**Figure 2** and **Figure 4**). Additionally, those four conditions considered together did not change driving behaviors significantly as revealed by the inter-vehicular time (**Figure 6**).

FIGURE LEGENDS:

Figure 1: Subjective mood assessed by the BMIS under no music and music background conditions. (**A**) Pleasant-unpleasant level from 16 (most unpleasant situation) to 64 (most pleasant situation). (**B**) Arousal-calm level from 12 (minimal activation level) to 48 (maximum arousal level). (**C**) Positive-tired level from 7 (most tired level) to 28 (most positive level). (**D**) Negative-relaxed level from 6 (most negative level) to 24 (most relaxed level). Error bars represent standard errors.

Figure 2: Subjective mood assessed by the BMIS under the four different auditory backgrounds conditions. (**A**) Pleasant-unpleasant level from 16 (most unpleasant situation) to 64 (most pleasant situation). (**B**) Arousal level from 12 (minimal activation level) to 48 (maximum arousal level). (**C**) Positive-tired level from 7 (most tired level) to 28 (most positive level). (**D**) Negative-relaxed level from 6 (most negative level) to 24 (most relaxed level). Error bars represent standard errors.

Figure 3: Mean heart rate and heart rate variability under no music and music background conditions. (**A**) Mean heart rate. (**B**) Mean heart rate variability. Error bars represent standard errors.

Figure 4: Mean heart rate and heart rate variability under the four different auditory backgrounds conditions. (**A**) Mean heart rate. (**B**) Mean heart rate variability. Error bars represent standard errors.

Figure 5: Mean inter-vehicular time and inter-vehicular time standard deviation under no music and music background conditions. (**A**) Mean inter-vehicular time. (**B**) Mean inter-vehicular time standard deviation. Error bars represent standard errors.

Figure 6: Mean inter-vehicular time and inter-vehicular time standard deviation under the four different auditory backgrounds conditions. (**A**) Mean inter-vehicular time. (**B**) Mean inter-vehicular time standard deviation. Error bars represent standard errors.

DISCUSSION:

The proposed method is well suited for cognitive ergonomic investigations as it offers an excellent compromise between experimental control and ecological vailidity[16]. If a strong experimental control is required to ensure that the collected results are related to the experimental manipulations, no results are of interest if restricted to the experimental conditions. Indeed, scientific results are of interest if transferable to real life situations. These assertions do not mean that only real-life experiments are valuable, but rather stress that the ecological validity of a method depends on the objectives of the research[16]. The reported method should be favored by researchers that are interested in human cognition and behaviors in real life situations (i.e., car driving) and that are in need of a good experimental control. Of course, the reported method is not reproducing real life driving situations, where a variety of sounds/noises can interfere with the impact of music listening on driving behaviors. In real driving situations, as drivers' own safety is engaged, this could also impact on the results. However, with the method proposed here, the driving task is not broken down and drivers can drive as they usually do in a simulated environment where the events (i.e., car to follow speed changes) can be reproduced accurately from a condition to the other and from a participant to the other. The proposed method also has limitations. Driving is a complex activity and the car-following task reproduced here is just one driving task among many other possible driving tasks. In the car-following task, the focus is set on speed control, but lateral control, as well as tactical and strategical tasks, which engage different levels of cognitive control and neural circuits are not investigated[23]. In addition, the brief duration of the protocol is not sufficient to investigate fatigue, distraction or mind wandering issues for instance.

Fortunately, the proposed method can be adjusted depending on the experimental needs. Here, and in line with previous studies on the impact of driving with music[24,25], only the well-known car-following task[26] has been used. In the future studies, other driving situations implying different visual explorations strategies[27] could also be considered and added to the experimental protocol.

Irrespective of these possible adaptations of the protocol, a familiarization period with the driving simulator is required to ensure that participants are familiar with the vehicle dynamics and properly installed. In the same vein, the quality and intensity of music tracks, as well as loudspeaker quality are critical to unsure the method reproducibility.

Human emotions are classically considered as a combination of two orthogonal dimensions[28–31]: valence (from negative affect to positive affect) and arousal (from deactivation to activation). For instance, sadness is associated with a highly negative valence (i.e., unpleasant) but is neutral in terms of activation[31]. A future research direction would be to further investigate these two dimensions of emotions using music listening. Besides, music is a complex stimulus that could be described based on its own properties (e.g., intensity, tempo, rhythm, mode). Music can also be described based on its effects on the listeners. As such a given music track can have a different impact on each individual listener. Here we investigated the influence of listening to the favorite music track, along with a tempo manipulation, on driving performances. In the future, other music dimensions could be investigated along with differential impact depending on the listener.

Future applications of the method could also be made beyond music listening investigations. As such, research topics such as texting while driving[32], mind-wandering behind the wheel[33], and driving automation[34–37] could benefit from the proposed method.

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DISCLOSURES:

The authors have nothing to disclose.

REFERENCES:

1. Lee, J.D. Fifty Years of Driving Safety Research. (Cover story). *Human Factors*. **50** (3), 521-528, doi: 10.1518/001872008X288376. (2008).

2. Zatorre, R.J., Peretz, I. *The Biological Foundations of Music: Annals of the New York Academy of Sciences*. sur <http://www.nyas.org/publications/Annals/Detail.aspx?cid=543a809f-1f08-4457-914c-76c78fcc3b48>. New York. (2001).

3. Glacken, C.J. *Traces on the Rhodian shore: Nature and culture in Western thought from ancient times to the end of the eighteenth century*. Univ of California Press. (1973).

4. Schäfer, T., Sedlmeier, P., Städtler, C., Huron, D. The psychological functions of music listening. *Frontiers in Psychology*. **4** (AUG), doi: 10.3389/fpsyg.2013.00511 (2013).

5. Rentfrow, P.J., Gosling, S.D. The do re mi's of everyday life: the structure and personality correlates of music preferences. *Journal of personality and social psychology*. **84** (6), 1236 (2003).

6. Dibben, N., Williamson, V.J. An exploratory survey of in-vehicle music listening. *Psychology of Music*. **35** (4), 571-589 (2007).

7. Juslin, P.N., Laukka, P. Expression, Perception, and Induction of Musical Emotions: A Review and a Questionnaire Study of Everyday Listening. *Journal of New Music Research*. **33** (3), 217-238, doi: 10.1080/0929821042000317813 (2004).

8. Västfjäll, D. Emotion Induction through Music: A Review of the Musical Mood Induction Procedure. *Musicae Scientiae*. **5** (1 suppl), 173-211, doi: 10.1177/10298649020050S107 (2002).

9. Mayer, J.D., Gaschke, Y.N., Braverman, D.L., Evans, T.W. Mood-Congruent Judgment Is a General Effect. *Journal of Personality and Social Psychology*. **63** (1), 119-132, doi: 10.1037/0022-3514.63.1.119 (1992).

10. Lewis, P.A., Critchley, H.D., Smith, A.P., Dolan, R.J. Brain mechanisms for mood congruent memory facilitation. *NeuroImage*. **25** (4), 1214-1223, doi: 10.1016/j.neuroimage.2004.11.053 (2005).

11. Blaney, P.H. Affect and memory: a review. *Psychological bulletin*. **99** (2), 229 (1986).

12. Wiesenthal, D.L., Hennessy, D.A., Totten, B. The Influence of Music on Driver Stress1. *Journal of applied social psychology*. **30** (8), 1709-1719 (2000).

13. van der Zwaag, M., Janssen, J.H., Nass, C., Westerink, J., Chowdhury, S., de Waard, D. Using music to change mood while driving. *Ergonomics*. **56** (10), 1504-14, doi: 10.1080/00140139.2013.825013 (2013).

14. Jallais, C., Gabaude, C., Paire-Ficout, L. When emotions disturb the localization of road elements: Effects of anger and sadness. *Transportation research part F: traffic psychology and behaviour*. **23**, 125-132 (2014).

15. Pêcher, C., Lemercier, C., Cellier, J. Emotions drive attention: Effects on driver's behaviour. *Safety Science*. **47** (9), 1254-1259, doi: 10.1016/j.ssci.2009.03.011 (2009).

16. Hoc, J.-M. Towards ecological validity of research in cognitive ergonomics. *Theoretical Issues in Ergonomics Science*. **2** (3), 278-288, doi: 10.1080/14639220110104970 (2001).

17. Kaptein, N., Theeuwes, J., Van Der Horst, R. Driving simulator validity: Some considerations. *Transportation Research Record: Journal of the Transportation Research Board*. (1550), 30-36 (1996).

18. Filliard, N., Icart, E., Martinez, J.-L., Gerin, S., Merienne, F., Kemeny, A. Software assembly and

open standards for driving simulation. *Proceedings of the Driving simulation conference Europe 2010*. 99–108 (2010).

19. Dalton, B.H., Behm, D.G. Effects of noise and music on human and task performance: A systematic review. *Occupational Ergonomics*. **7**, 143–152 (2007).

20. Mayer, J.D., Gaschke, Y.N. Brief Mood Introspection Scale (BMIS). *Psychology*. **19** (3), 1995–1995, doi: 10.1037/0022-3514.55.1.102 (2001).

21. Niedenthal, P.M., Dalle, N. Le mariage de mon meilleur ami: Emotional response categorization and naturally induced emotions. *European Journal of Social Psychology*. **31** (6), 737–742, doi: 10.1002/ejsp.66 (2001).

22. Dalle, N., Niedenthal, P.M. La réorganisation de l'espace conceptuel au cours des états émotionnels. *Annee Psychologique*. **103** (4), 585–616, doi: 10.3406/psy.2003.29653 (2003).

23. Navarro, J., Reynaud, E., Osiurak, F. Neuroergonomics of car driving: A critical meta-analysis of neuroimaging data on the human brain behind the wheel. *Neuroscience & Biobehavioral Reviews*. **95**, 464–479, doi: 10.1016/J.NEUBIOREV.2018.10.016 (2018).

24. Ünal, A.B., de Waard, D., Epstude, K., Steg, L. Driving with music: Effects on arousal and performance. *Transportation Research Part F: Traffic Psychology and Behaviour*. **21**, 52–65, doi: 10.1016/j.trf.2013.09.004 (2013).

25. Navarro, J., Osiurak, F., Reynaud, E. Does the Tempo of Music Impact Human Behavior Behind the Wheel? *Human Factors*. **60** (4), 556–574, doi: 10.1177/0018720818760901 (2018).

26. Brackstone, M., Mcdonald, M. Car-following : a historical review. *Transportation Research Part F: Traffic Psychology and Behaviour*. **2**, 181–196 (2000).

27. Chapman, P.R., Underwood, G. Visual search of driving situations: Danger and experience. *Perception*. **27** (8), 951–964, doi: 10.1068/p270951 (1998).

28. Russell, J.A. A Circumplex Model of Affect. *Journal of Personality and Social Psychology*. **39** (6), 1161–1178, doi: 10.1037/h0077714 (1980).

29. Russell, J.A. Core affect and the psychological construction of emotion. *Psychological review*. **110** (1), 145–72, doi: 10.1037/0033-295X.110.1.145 (2003).

30. Posner, J., Russell, J.A., Peterson, B.S. The circumplex model of affect: an integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and psychopathology*. **17** (3), 715–34, doi: 10.1017/S0954579405050340 (2005).

31. Feldman Barrett, L., Russell, J.A. Independence and Bipolarity in the Structure of Current Affect. *Journal of Personality and Social Psychology*. **74** (4), 967–984, doi: 10.1037/0022-3514.74.4.967 (1998).

32. Caird, J.K., Johnston, K.A., Willness, C.R., Asbridge, M., Steel, P. A meta-analysis of the effects of texting on driving. *Accident Analysis and Prevention*. **71**, 311–318, doi: 10.1016/j.aap.2014.06.005 (2014).

33. He, J., Becic, E. Mind Wandering Behind the Wheel: Performance and Oculomotor Correlates. doi: 10.1177/0018720810391530.Copyright (2009).

34. Navarro, J., François, M., Mars, F. Obstacle avoidance under automated steering: Impact on driving and gaze behaviours. *Transportation Research Part F: Traffic Psychology and Behaviour*. **43**, 315–324, doi: 10.1016/j.trf.2016.09.007 (2016).

35. Navarro, J., Yousfi, E., Deniel, J., Jallais, C., Bueno, M., Fort, A. The impact of false warnings on partial and full lane departure warnings effectiveness and acceptance in car driving. *Ergonomics*. **59** (12), 1553–1564, doi: 10.1080/00140139.2016.1158323 (2016).

36. Navarro, J., Deniel, J., Yousfi, E., Jallais, C., Bueno, M., Fort, A. Influence of lane departure warnings onset and reliability on car drivers' behaviors. *Applied Ergonomics*. **59**, 123‐131, doi: 10.1016/j.apergo.2016.08.010 (2017).
37. Navarro, J. Human–machine interaction theories and lane departure warnings. *Theoretical Issues in Ergonomics Science*. **18** (6), 519‐547, doi: 10.1080/1463922X.2016.1243274 (2017).

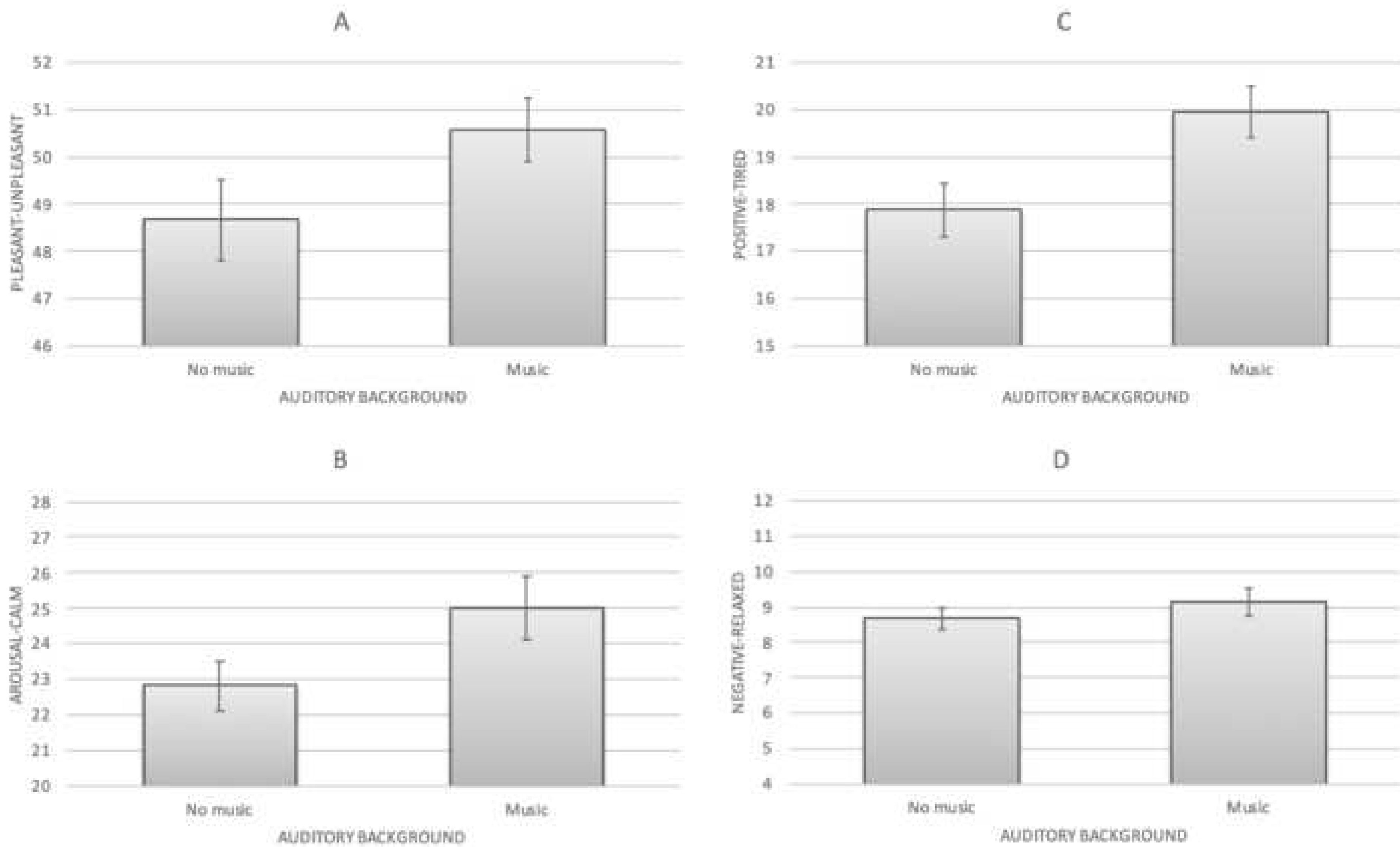
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Figure2

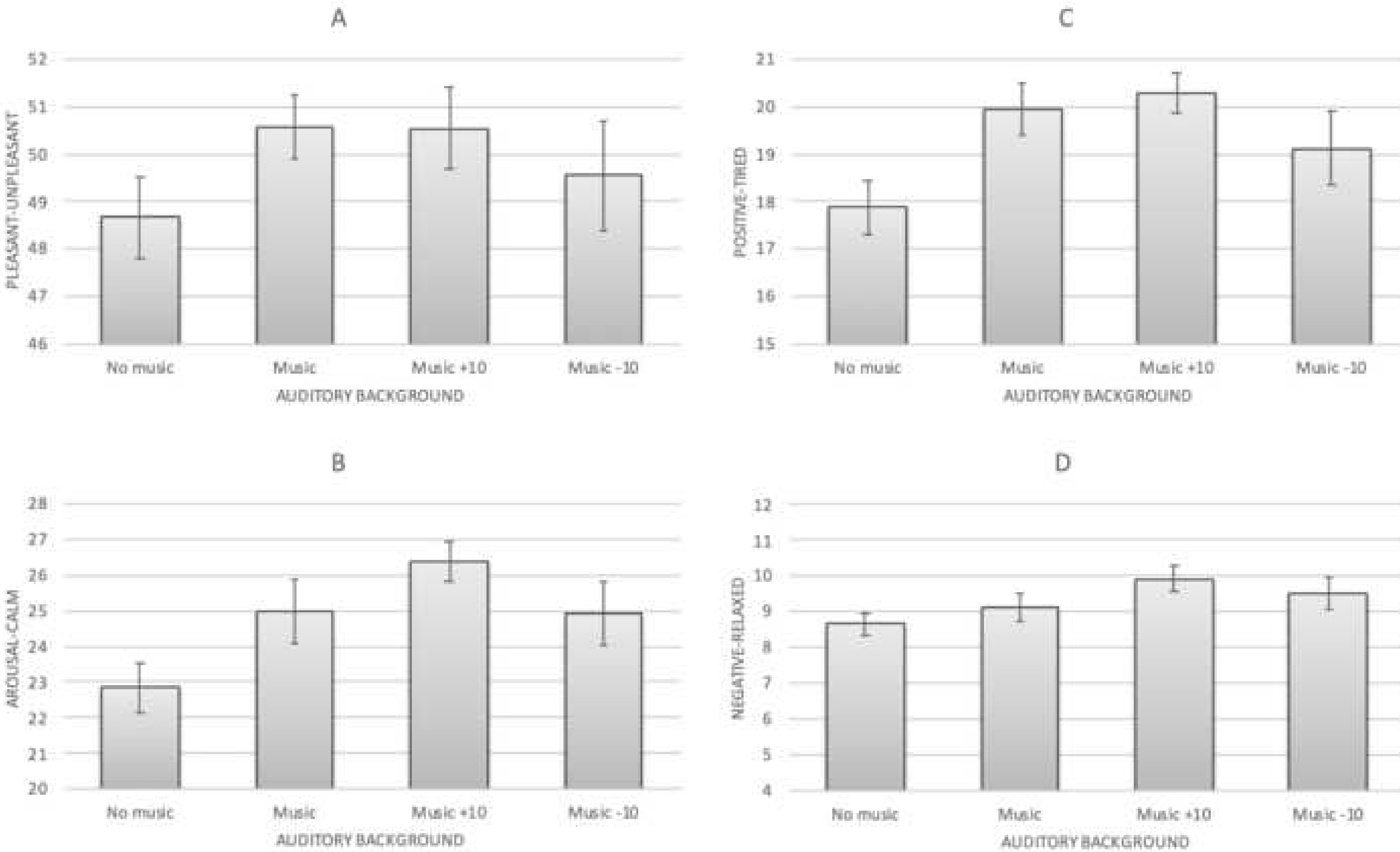
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Figure3

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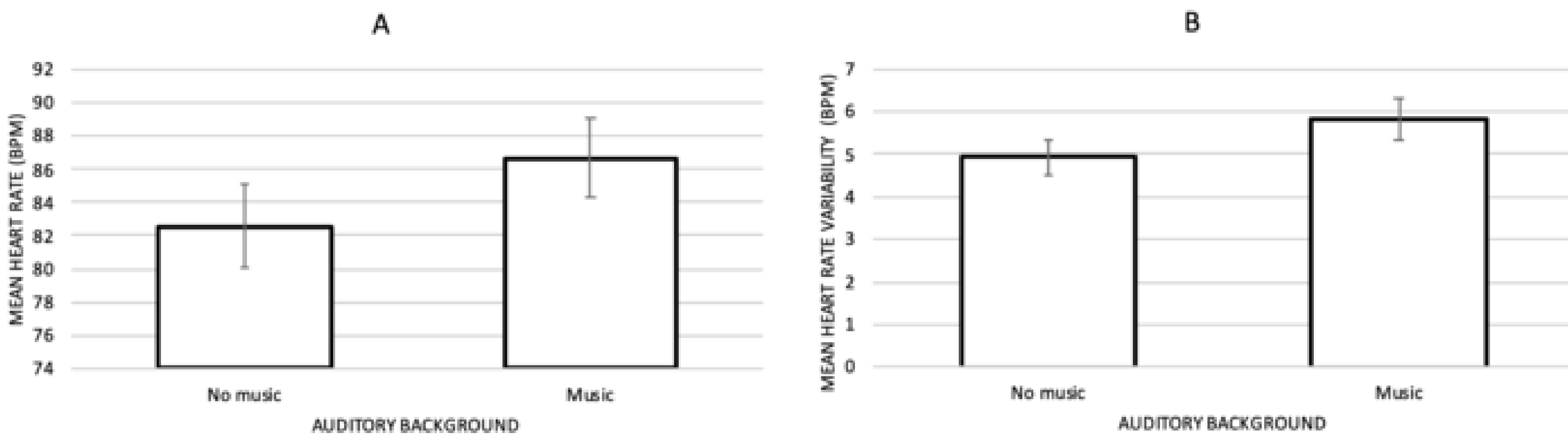

Figure4

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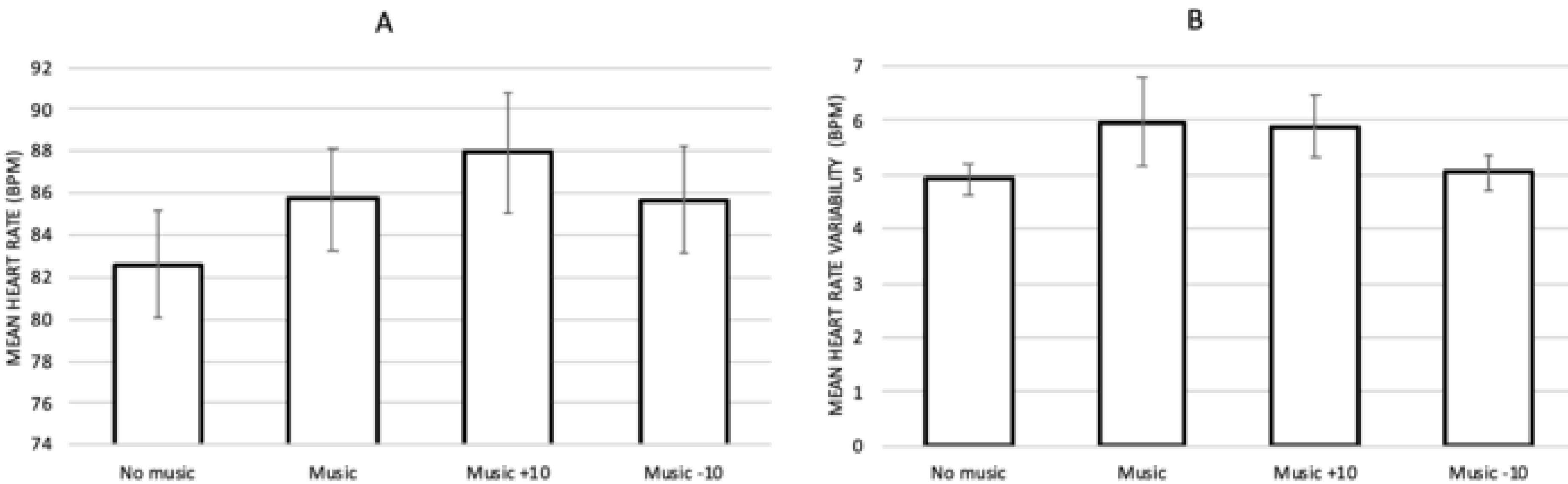

Figure5

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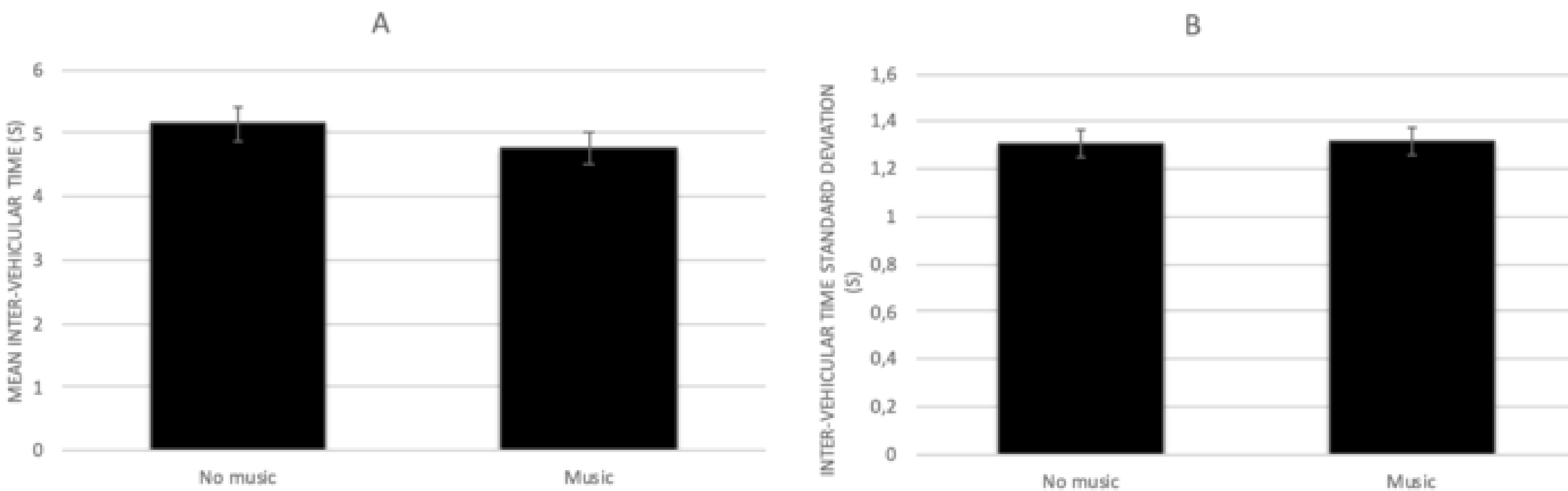

Figure6

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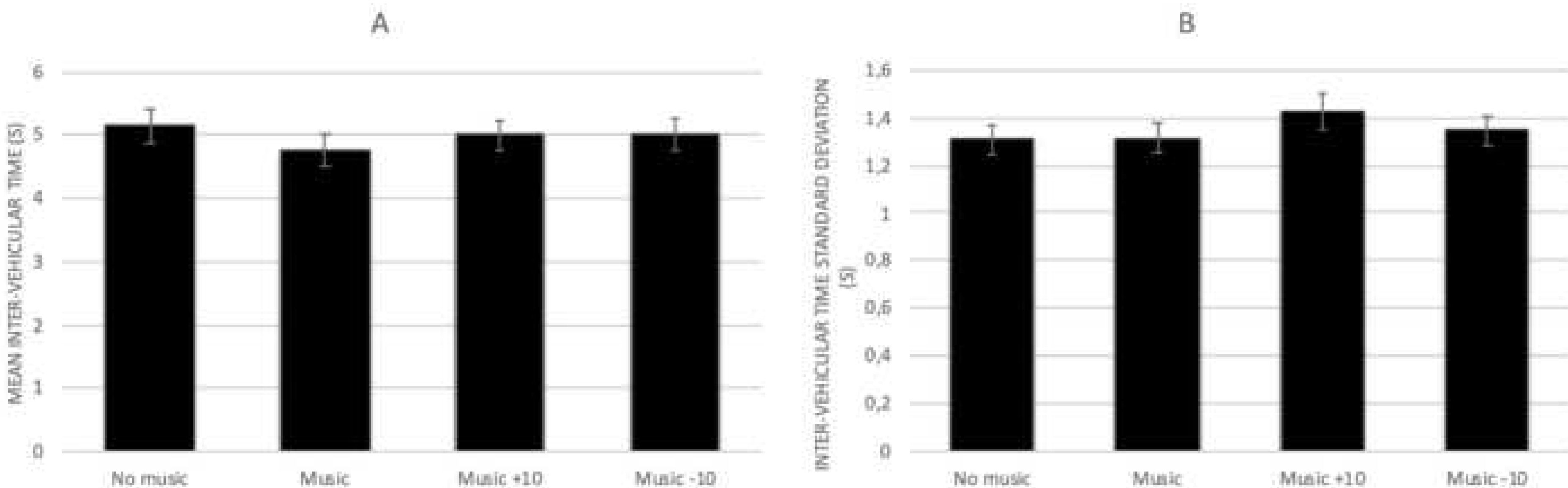

Name of Material/ Equipment	Company	Catalog Number
Audacity software	Audacity	Open source
Driving simulator	Université de Sherbrooke	BB sim
Polar watch with heart rate monitor	Polar	RC3
Speakers	Yamaha	MSP3
Steering wheel and pedals	Logitech	G27

Comments/Description

https://www.audacityteam.org

https://www.polar.com/fr

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Author(s): J. Navarro, F. Osiurak, V. Gaujoux, E. Reynaud, M.C. Ouimet

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CORRESPONDING AUTHOR:

Name: NAVARRO Jordan

Department: Laboratoire d'Etude des Mécanismes Cognitifs

Institution: University Lyon 2

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Response to reviewers.

Dear Dr. Steindel,

Please find attached the revised version of the manuscript including the changes, along with a tracked version of the paper. In the following paragraphs you will find our responses (in black) to each of the points raised by the Reviewers and Editor (in grey). We hope that the modifications made to the manuscript further improved the manuscript.

Sincerely yours,
The authors

Editorial comments:
1. Additional details are required:
5.1: Please provide an example of the BMIS questionnaire as a supplemental file.
E.1. An example of the BMIS questionnaire as a supplemental file has been added. References about the French validation of the BMIS were also included in the MS.

5.2: When was the heart rate monitoring attached to the driver? This is not mentioned previously.
E.2. Participants are equipped with the heart rate monitoring device before to take place on the driving simulator (described at MS section 1.5). Point 4.4 has been added to explain that the heart rate data recording is made by musical background condition.

Line 271-273: $p = .15$ or = < .14?
E.3. IVT was not significantly impacted by the background condition. The *p* value is p=.14

2. Can a picture of the set up be provided?
E.4. A picture of the set up has been added as supplemental file.

Reviewers' comments:

Reviewer #1:

Major Concerns:
I feel this paper could benefit from a very thorough review by a proficient editor.
R.1.1. The manuscript has been checked again.

Graphics could be much better. I urge authors to develop better charts to present their data with higher quality.
R.1.2. The Figures have been improved according to editorial recommendations at the first review of the manuscript.

Minor Concerns:
The first paragraph of the introduction while it is an obvious statement, it's not a statement that a scientific article could gain benefit from.
R.1.3. The sentence has been changed according to R1 comment at the first review of the manuscript. Now the first sentence "*Car driving activity has spread up extremely quickly over the last decades and is now a daily activity for many individuals in modern societies*." introduce the manuscript by putting some emphasis on the importance of car-driving. This is relevant to us as the methodology presented focus on car-driving.

Although authors claim "an exhaustive literature review" I cannot find enough discussion or a well structured literature review section or discussion as a proof of this statement.
R.1.5. This exhaustive literature review was conducted by another group of researchers. The reference to this work is available at the end of the quoted sentence. To avoid any confusion, the sentence was changed during the first review and now clearly states that "*Based on an exhaustive literature review, Schäfer et al., found about 130 different non-redundant functions associated to music listening and three music listening meta-functions were then identified: (1) arousal and mood regulation, (2) self-awareness achievement and (3) social relatedness expression*[4]."

"Protocol" section of this paper:
- Please provide a sufficient introduction for the protocol.
R.1.6. A figure of the set up and an example of BMIS questionnaire have been added as supplemental files. Further details on the driving scenario and the analysis performed on the physiological data were also added.

- Please explain your advertisement method to acquire participants?
R.1.7. This information was added at the beginning of the protocol.

What is the method of analysis that is being used here? Mentioning that the difference is significant is not enough.
R.1.8. The method of analysis is presented in the first paragraph of the representative results.

Reviewer #2:

Manuscript Summary:
The authors made a good effort revising the manuscript according to the review comments.
R.2.1. The authors are very grateful to R2 for his/her general appreciation of the effort of revision on the submitted MS.

Major Concerns:
However, if in line with the journal's guideline, I would still suggest adding more detailed descriptions of the driving scenario/environment and analysis details of the physiological data. These detailed descriptions are essential for others to understand

the exact material/procedure that would enable replication of the protocol. If these are not required by the journal, then I do not have any further comment.
R.2.2. Following R2 insights more details are now provided on both the driving scenario/environment (new paragraph 4.6) and the analysis performed on the physiological data (add to paragraph 5.2).

TITLE:

Driving Under the Influence: How Music Listening Affects Driving Behaviors

AUTHORS AND AFFILIATIONS:

Jordan Navarro[1,2], François Osiurak[1,2], Vivien Gaujoux[1], Marie Claude Ouimet[3] & Emanuelle Reynaud[1]

[1]Laboratoire d'Etude des Mécanismes Cognitifs (EA 3082), University Lyon 2, France
[2] Institut Universitaire de France, Paris, France
[3] Faculté de médecine et des sciences de la santé, Université de Sherbrooke, Longueuil, Canada

Corresponding Author:
Jordan Navarro
Jordan.Navarro@univ-lyon2.fr

Email Addresses of Co-authors**:**
François Osiurak (Francois.Osiurak@univ-lyon2.fr)
Vivien Gaujoux (Vivien.Gaujoux@univ-lyon2.fr)
Marie Claude Ouimet (Marie.Claude.Ouimet@USherbrooke.ca)
Emanuelle Reynaud (Emanuelle.Reynaud@univ-lyon2.fr)

KEYWORDS:

Music, tempo, driving behaviors, driving simulation, car-following task, speed control, level of arousal, mood.

SUMMARY:

Here, we present a protocol to assess driving behaviors while following a vehicle in a simulated driving environment. The presented protocol is used to compare the impact of different auditory backgrounds on driving behaviors.

ABSTRACT:

Car driving is a daily activity for many individuals in modern societies. Drivers often listen to music while driving. The method presented here investigates how listening to music influences driving behaviors. A driving simulation was selected because it offers both a well-controlled environment and a good level of ecological validity. Driving behaviors were assessed through a car-following task. In practice, participants were instructed to follow a lead vehicle as they would do in real life. The lead vehicle speed changed over time requiring constant speed adjustments for the participants. The inter-vehicular time was used to assess driving behaviors. To complement the driving behaviors, the subjective mood and physiological level of arousal were also collected. As such, the results collected using this method offer insights on both the human internal state (i.e., subjective mood and physiological arousal) and driving behaviors in the car following task.

INTRODUCTION:

Car driving activity has increased quickly over the last decades and is now a daily activity for many individuals in modern societies. In line with this growth, car-driving activity has become a hot topic of investigation for the human factor community[1].

There is an extremely limited amount of major cultural activities that typically define humankind regardless of the population and the period of history considered[2]. Music is one of these activities along with tool use and symbolic reasoning underpinning language abilities[3]. Playing and listening to music is therefore a crucial individual and social activity. Based on an exhaustive literature review, Schäfer et al. found about 130 different non-redundant functions associated to music listening and three music listening meta-functions were then identified: (1) arousal and mood regulation, (2) self-awareness achievement and (3) social relatedness expression[4]. As a consequence, people are frequently listening to music in a variety of situations and locations[5]. Among those situations, listening to music while driving is extremely common with drivers reporting listening to music during about three quarters of their driving time[6].

Music listening is known to impact the listener's emotional state[7] and thus to induce mood changes in a variety of situations and research areas[8]. According to the mood congruency theory, a person's behavior is related to his/her mood[9] with evidence gained from both neuroimaging[10] and behavioral experiments[11]. Following this rationale, music listening can change drivers' mood, which in turn can change driving behaviors.

Musically-induced mood changes while driving was found to result in performance improvements under certain conditions or impairments under other conditions. On one hand, in complex and highly demanding driving environments, calm music was found to mitigate affective states: it has a softening effect on negative emotions, reduces the level of stress and improves drivers relaxation and calm[12]. This relaxing effect was reported to be more efficient when using abrupt music changes compared to gradual music changes[13]. On the other hand, people were slower to detect hazards in driving scenes when anger was previously induced through music and guided imagery compared with neutral mood performances[14]. Happy music listening while driving was also found to be detrimental to lateral control efficiency whereas sad music had no significant effect on lateral control of the vehicle[15]. In brief, drivers' mood can impact driving performances in opposite ways depending on the music and associated mood induction and on the driving situation considered.

The purpose of the method reported here is to offer an experimentally well-controlled driving situation to investigate the impact of music listening on driving behaviors. To ensure the reproducibility of the driving situation, a method based on driving simulation has been implemented. At the first glance, a driving simulation might be considered as a degraded version of real driving investigations. However, the reality is more complex, and a given experimental set up cannot be considered as the best experimental solution in absolute terms. Rather the best experimental set up is the one that suits the most accurately the needs of the investigation concerned[16]. If real car-driving is the experimental set-up that best reproduces the everyday life driving situations, it also comes with some drawbacks: driver safety in case of experimental manipulations, potential impairments in terms of driving performances, and difficulties in the control of the driving environment, including traffic, weather conditions, light conditions, level of ambient noise, etc. Conversely, if driving simulators are not as realistic as real vehicles, experimental conditions and manipulations can be strictly controlled and replicated[17]. As a result, different participants can be exposed to the exact same experimental conditions. In addition, experimental manipulations potentially impairing driving performances are made possible as only virtual safety (and not real safety) is engaged. Altogether, a driving simulation offers an excellent compromise between the need to conserve the driving activity natural (i.e., external validity) and the need for a strong experimental control (i.e., internal validity).

PROTOCOL:

All methods described here have been approved by the Ethics Committee of the Department of Psychology of University Lyon 2 and informed consent was obtained from all participants. Participants were recruited by means of notices posted in the local community and at the University.

1. Participants

1.1. Ensure that participants have a driving license and at least two years of driving experience.

1.2. Ensure that participants have normal or corrected to normal vision and audition.

1.3. Ensure that participants do not suffer from a mental illness (e.g., schizophrenia).

1.4. Recruit a similar number of females and males.

1.5. Equip participants with a heart rate belt linked to a watch to monitor heart rate.

1.6. Ask participants to choose freely their own preferred music track (examples of participants choice: Uptown Funk by Mark Ronson featuring Bruno Mars or Cheerleader by OMI). Ask participants to provide that music track on a USB stick. Use this track to create different musical backgrounds for the experiment (see section 3).

2. **Driving simulation**

NOTE: The results are described based on a new driving simulator at our research lab, a BB_Sim developed at the Université de Sherbrooke, which includes one computer, three screens, and a steering wheel and acceleration and braking pedals for driving controls. The initial study was conducted with a different driving simulator using the open-source OpenSD2S software[18].

2.1. Set the driving simulation driving noise (i.e., engine of the driven vehicle) at ± 25dB.

2.2. Seat the participant in front of the simulator, approximately 60 cm from the screens (three screens located in front of the participant, 48 cm x 30 cm each, covering a total of 137.52° of the visual angle on the horizontal axis and 28.65° of the visual angle on the vertical axis), in a modified car seat.

2.3. Let the participant adjust the distance between the seat and the pedals with the handle underneath the seat.

2.4. Once the participant is comfortably positioned, provide instructions on using the features of the simulator (i.e., how to interact with the acceleration and braking pedals and the steering wheel).

2.5. Inform the participant about simulation sickness that can sometimes occur, and let the participant know that the simulation will be stopped at any time if necessary.

2.6. Use a rural roadway with one traffic lane per direction with five left bends and five right bends and without any traffic.

3. Musical background

3.1. Use software to modify the tempo of the music, without any pitch modification.

3.2. Create four auditory backgrounds for each participant:
No Music - with no additional music played.
Music - each participant preferred music track without modification.
Music +10 - each participant preferred music track with an increased tempo. The tempo is increased by 10 % of the regular tempo.
Music -10 - each participant preferred music track with a decreased tempo. The tempo is decreased by 10 % of the regular tempo.

3.3. Control the intensity of the music. Music intensity is known to modify driving performances[19]. Set the intensity to 75 dB for all auditory backgrounds but the No Music condition.

3.4. Use a software to play one of the four musical backgrounds for the complete duration of each drive.

3.5. Play the music on two lateral powered monitor speakers located on the right and on the left of the participant.

4. Simulated car-following task

4.1. Provide instructions concerning the task: “Drive as you would do in a real-life situation. Your goal is to follow the vehicle in front of you at a close but safe constant distance, as if following a friend on an unknown route. Inform the participant that there is no traffic or obstacles on the path."

4.2. Start the simulation with a training phase in order to familiarize the participant with the driving simulator, the simulated environment, the vehicle controls and the car-following task. When the participant feels comfortable, stop the training phase.

4.3. Proceed with the experimental drives. Launch the simulated car-following task and one of the four musical background.

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~~4.3.~~4.4. Start a recording of heart rate data at the beginning of each simulated car-following task and end it at the end of that driving task.

4.5. For the simulated car driving task, have the driver first drive for 50 meters before stopping at a "Stop" sign. Once the participant's vehicle has stopped, a leading vehicle appears on the road at the left of the intersection. Instruct the participant to follow the vehicle. After an initial phase in which the speed of the leading vehicle is stationary and set at 20 kph, allowing the driven vehicle to catch up, its speed then varies sinusoidally between 45 kph and 70 kph within each period of 60 seconds for a total of 3 minutes. Then, ask the participant to stop driving.

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~~4.4.~~4.6. For the car-following task, u~~U~~se a ~~two lane~~two-lane road with opposition traf~~f~~fic directions~~ section car-following task, participants~~. In order to provide a realistic driving ~~environement~~environment, use a road section with a balanced number of left (n=5) and right bends (n=5) with various ~~degrees~~radii of curvature from 45 to 300 meters. Also add visual elements on the edges of the road section such as trees, barriers, ~~and should be a rural road The curvature~~ fields, and landform.

~~4.5.~~4.7. Repeat the car-following task for each of the four musical backgrounds. The car-following task takes about 4 minutes (3 minutes of actual car-following plus beginning and ending of the driving simulation).

NOTE: The duration of the car-following task can be extended if required.

~~4.6.~~4.8. Take a 5 min break between each car-following task to reduce carryover effects.

~~4.7.~~4.9. Counterbalance the order of presentation of the four musical backgrounds between participants using a Latin square design.

5. **Data collection**

5.1. Collect the participants' subjective mood after each condition using the Brief Mood Introspection Scale (BMIS)[20] validated in French[21, 22]. This questionnaire provides data on participants' mood on four mood dimensions: pleasant/unpleasant, arousal/calm, positive/tired and negative/relaxed.

5.2. Collect physiological measures. Compute the mean heart rate and heart rate variability over the entire drive for each experimental condition using the data recorded by the heart rate monitoring watch at a sample per second. In practice, compute mean heart rate by averaging all the data collected during ~~that~~each experimental condition ~~. In addition, compute~~and -heart rate variability ~~? through the~~by calculating the standard deviation ~~of~~on the same data.

5.3. Measure objective driving behaviors through the mean inter-vehicular time and the inter-vehicular time variability. Record both driven and leading vehicle position and speed at each time step at a sample rate of 60 Hz.

5.3.1. At each time step, compute the inter-vehicular time as the time required for the driven vehicle to reach the position of the lead vehicle if the position of the lead vehicle was frozen and the speed of the driven vehicle was constant.

5.3.2. Average all the values collected for a drive to obtain the mean inter-vehicular time and compute the standard deviation on those values to obtain the inter-vehicular time variability.

NOTE: Several variables can be computed to qualify driving behaviors during a car-following task. The inter-vehicular time is particularly well-suited as it offers an indication of the safety margin between the driven vehicle and the lead vehicle chosen by the driver.

REPRESENTATIVE RESULTS

The main comparisons are based on the following experimental conditions. The first experimental condition is No Music versus Music: a comparison between the No Music background and the individual preferred Music background using a pairwise *t*-test. These analyses were meant to assess the influence of listening to preferred music compared to a control condition without music. The second experimental condition is four different musical backgrounds: a comparison between No Music, Music, Music +10 and Music -10 corresponding to a music tempo manipulation compared to a control condition without music, using repeated measures ANOVAs.

Subjective mood

As compared with No Music, Music had a significant effect on subjective mood as observed on three of the four dimensions of the Brief Mood Introspection Scale (**Figure 1**). Significant differences were found for the pleasant-unpleasant ($t(23) = -2.75$; $p < .01$), arousal-calm ($t(23) = -2.67$; $p < .01$) and positive-tired ($t(23) = 3.54$; $p < .001$) dimensions. No significant differences were observed for the negative-relaxed dimension ($t(23) = 1.05$; $p = .153$).

[Place Figure 1 here]

Considering all four auditory backgrounds, a significant effect on subjective mood as observed on the four dimensions of the BMIS (**Figure 2**). Significant differences were found for the pleasant-unpleasant ($F(3,69) = 2.75$; $p < .05$), arousal-calm ($F(3,69) = 7.74$; $p < .001$), positive-tired ($F(3,69) = 7.36$; $p < .001$) and negative-relaxed ($F(3,69) = 3.24$; $p < .03$) dimensions.

[Place Figure 2 here]

Physiological measures

The mean heart rate was significantly different for the No Music and Music backgrounds ($t(18) = -5.05$; $p < .001$; **Figure 3**). The heart rate variability was not significantly impacted by the background condition ($t(18) = -1.58$; $p = .07$; **Figure 3**).

[Place Figure 3 here]

The mean heart rate was significantly different under the four auditory background conditions ($F(3,51) = 4.25$; $p < .01$; **Figure 4**). The heart rate variability was not significantly impacted by the background condition ($F(3,51) = .94$; $p = .43$; **Figure 4**).

[Place Figure 4 here]

Driving behaviors

The mean inter-vehicular time was significantly different for the No Music and Music backgrounds ($t(23) = 2.53$; $p < .01$; **Figure 5**). The inter-vehicular time standard deviation was not significantly impacted by the background condition ($t(23) = -0.11$; $p = .55$; **Figure 5**).

[Place Figure 5 here]

The mean inter-vehicular time was not significantly different under the four auditory background conditions ($F(3,69) = 1.88$; $p = .14$; **Figure 6**). Similarly, the inter-vehicular time standard deviation was not significantly impacted by the background condition ($F(3,69) = 1.57$; $p = .20$; **Figure 6**).

[Place Figure 6 here]

Listening to music or not (No Music versus Music conditions) while driving was found to have a significant effect on subjective mood, physiological level of arousal and on driving performances. In more detail, listening to favorite music behind the wheel was found to impact positively on the mood, leading to a higher level of pleasantness, arousal and a more positive mood (**Figure 1**). The comparison between no music and music backgrounds revealed a significant influence of music listening on drivers mean heart rate. Music increased the mean heart rate. In line with subjective data, this increase can be interpreted as an increase in arousal induced by music listening (**Figure 3**). It is assumed that the increase of arousal produced by music listening translates into driving behaviors modifications. In the car-following task, drivers had a smaller inter-vehicular time while listening to music compared with the control condition without music to listen (**Figure 5**). This can be interpreted as a reduction of drivers' safety margin with the vehicle to follow in an external assessment perspective (i.e., absolute safety margin). But, from the drivers' perspective, the inter-vehicular time reduction is most probably adjusted depending on their own perceived abilities. With a higher level of arousal, faster detections and responses to follow the speed changes of the leading vehicle can be made. Still from drivers' perspective, a reduction of the inter-vehicular time is required to maintain the same safety margin (i.e., relative safety margin). In sum, the experimental protocol reported here was found to be sensitive enough to reveal mood changes, physiological changes and driving behaviors changes for the comparison between no music and music conditions. The manipulation of the music tempo (i.e., four different auditory backgrounds comparison) did not translate into the same pattern of results. If all four dimensions of subjective mood and physiologically assessed arousal were found be significantly influenced by the auditory background, no clear impact of the music tempo was found. Indeed, music, music +10 and music -10 conditions had an insignificantly different effect on drivers' subjective mood and physiological arousal (**Figure 2** and **Figure 4**). And those four conditions considered together did not change significantly driving behaviors as revealed by the inter-vehicular time (**Figure 6**).

Figure legends:

Figure 1: Subjective mood assessed by the BMIS under no music and music background conditions. **(A)**. Pleasant-unpleasant level from 16 (most unpleasant situation) to 64 (most pleasant situation). **(B)**. Arousal-calm level from 12 (minimal activation level) to 48 (maximum arousal level). **(C)**. Positive-tired level from 7 (most tired level) to 28 (most positive level). **(D)**. Negative-relaxed level from 6 (most negative level) to 24 (most relaxed level). Error bars represent standard errors.

Figure 2: Subjective mood assessed by the BMIS under the four different auditory backgrounds conditions. **(A)**. Pleasant-unpleasant level from 16 (most unpleasant situation) to 64 (most pleasant situation). **(B)**. Arousal level from 12 (minimal activation level) to 48 (maximum arousal level). **(C)**. Positive-tired level from 7 (most tired level) to 28 (most positive level). **(D)**. Negative-relaxed level from 6 (most negative level) to 24 (most relaxed level). Error bars represent standard errors.

Figure 3: Mean heart rate (A) and heart rate variability (B) under no music and music background conditions. Error bars represent plus and minus one standard error.

Figure 4: Mean heart rate (A) and heart rate variability (B) under the four different auditory backgrounds conditions. Error bars represent standard errors.

Figure 5: Mean inter-vehicular time (A) and inter-vehicular time standard deviation (B) under no music and music background conditions. Error bars represent standard errors.

Figure 6: Mean inter-vehicular time (A) and inter-vehicular time standard deviation (B) under the four different auditory backgrounds conditions. Error bars represent standard errors.

DISCUSSION:

The proposed method is well suited for cognitive ergonomic investigations as it offers an excellent compromise between experimental control and ecological vailidity[16]. If a strong experimental control is required to ensure that the collected results are related to the experimental manipulations, no results are of interest if restricted to the experimental conditions. Indeed, scientific results are of interest if transferable to real life situations. These assertions do not mean that only real-life experiments are valuable, but rather stress that the ecological validity of a method depends on the objectives of the research[16]. The reported method should be favored by researchers that are interested in human cognition and behaviors in real life situations (i.e., car driving) and that are in need of a good experimental control. Of course, the reported method is not reproducing real life driving situations, where a variety of sounds/noises can interfere with the impact of music listening on driving behaviors for instance. In real driving situations, drivers' own safety is engaged, this could also impact on the results. But with the method proposed here, the driving task is not broken down and drivers can drive as they usually do in a simulated environment where the events (i.e., car to follow speed changes) can be reproduced accurately from a condition to the other and from a participant to the other. The proposed method also has limitations. Driving is a complex activity and the car-following task reproduced here is just one driving task among many other possible driving tasks. In the car-following task, the focus is set on speed control, but lateral control, as well as tactical and strategical tasks, that engage different level of cognitive control and neural circuits are not investigated[23]. In addition, the brief duration of the protocol is not sufficient to investigate fatigue, distraction or mind wandering issues for instance.

Fortunately, the proposed method can be adjusted depending on the experimental needs. Here, and in line with previous researches on the impact of driving with music[24, 25], only the well-known car-following task[26] has been used. In the future studies, other driving situations implying different visual explorations strategies for instance[27] could also be considered and added to the experimental protocol.

Irrespective of these possible adaptations of the protocol, a familiarization period with the driving simulator is required to ensure that participants are familiar with the vehicle dynamics and properly installed. In the same vein, music tracks quality, intensity, and loudspeaker quality are critical to unsure the method reproducibility.

Human emotions are classically considered as a combination of two orthogonal dimensions[28–31]: valence (from negative affect to positive affect) and arousal (from deactivation to activation). For instance, sadness is associated with a highly negative valence (i.e., unpleasant) but is neutral in terms of activation[31]. A future research direction would be to further investigate these two dimensions of emotions using music listening. Besides, music is a complex stimulus that could be described based on its own properties (e.g., intensity, tempo, rhythm, mode). Music can also be described based on its effects on the listeners. As such a given music track can have a different impact on each individual listener. Here we investigated the influence of listening to the favorite music track, along with a tempo manipulation, on driving performances. In the future other music dimensions could be investigated along with differential impact depending on the listener.

Future applications of the method could also be made beyond music listening investigations. As such, research topics such as texting while driving[32], mind-wandering behind the wheel[33], driving automation[34–37] could benefit from the proposed method.

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DISCLOSURES:

The authors have nothing to disclose.

REFERENCES:

1. Lee, J.D. Fifty Years of Driving Safety Research. (Cover story). *Human Factors*. **50** (3), 521‑528, doi: 10.1518/001872008X288376. (2008).
2. Zatorre, R.J., Peretz, I. *The Biological Foundations of Music: Annals of the New York Academy of Sciences*. sur <http://www.nyas.org/publications/Annals/Detail.aspx?cid=543a809f-1f08-4457-914c-76c78fcc3b48>. New York. (2001).
3. Glacken, C.J. *Traces on the Rhodian shore: Nature and culture in Western thought from ancient times to the end of the eighteenth century*. Univ of California Press. (1973).
4. Schäfer, T., Sedlmeier, P., Städtler, C., Huron, D. The psychological functions of music listening. *Frontiers in Psychology*. **4** (AUG), doi: 10.3389/fpsyg.2013.00511 (2013).
5. Rentfrow, P.J., Gosling, S.D. The do re mi's of everyday life: the structure and personality correlates of music preferences. *Journal of personality and social psychology*. **84** (6), 1236 (2003).
6. Dibben, N., Williamson, V.J. An exploratory survey of in-vehicle music listening. *Psychology of Music*. **35** (4), 571‑589 (2007).
7. Juslin, P.N., Laukka, P. Expression, Perception, and Induction of Musical Emotions: A Review and a Questionnaire Study of Everyday Listening. *Journal of New Music Research*. **33** (3), 217‑238, doi: 10.1080/0929821042000317813 (2004).
8. Västfjäll, D. Emotion Induction through Music: A Review of the Musical Mood Induction Procedure. *Musicae Scientiae*. **5** (1 suppl), 173‑211, doi: 10.1177/10298649020050S107 (2002).
9. Mayer, J.D., Gaschke, Y.N., Braverman, D.L., Evans, T.W. Mood-Congruent Judgment Is a General Effect. *Journal of Personality and Social Psychology*. **63** (1), 119‑132, doi: 10.1037/0022-3514.63.1.119 (1992).
10. Lewis, P.A., Critchley, H.D., Smith, A.P., Dolan, R.J. Brain mechanisms for mood congruent memory facilitation. *NeuroImage*. **25** (4), 1214‑1223, doi: 10.1016/j.neuroimage.2004.11.053 (2005).
11. Blaney, P.H. Affect and memory: a review. *Psychological bulletin*. **99** (2), 229 (1986).
12. Wiesenthal, D.L., Hennessy, D.A., Totten, B. The Influence of Music on Driver Stress1. *Journal of applied social psychology*. **30** (8), 1709‑1719 (2000).
13. van der Zwaag, M., Janssen, J.H., Nass, C., Westerink, J., Chowdhury, S., de Waard, D. Using music to change mood while driving. *Ergonomics*. **56** (10), 1504‑14, doi:

10.1080/00140139.2013.825013 (2013).

14. Jallais, C., Gabaude, C., Paire-Ficout, L. When emotions disturb the localization of road elements: Effects of anger and sadness. *Transportation research part F: traffic psychology and behaviour*. **23**, 125-132 (2014).
15. Pêcher, C., Lemercier, C., Cellier, J. Emotions drive attention: Effects on driver's behaviour. *Safety Science*. **47** (9), 1254-1259, doi: 10.1016/j.ssci.2009.03.011 (2009).
16. Hoc, J.-M. Towards ecological validity of research in cognitive ergonomics. *Theoretical Issues in Ergonomics Science*. **2** (3), 278-288, doi: 10.1080/14639220110104970 (2001).
17. Kaptein, N., Theeuwes, J., Van Der Horst, R. Driving simulator validity: Some considerations. *Transportation Research Record: Journal of the Transportation Research Board*. (1550), 30-36 (1996).
18. Filliard, N., Icart, E., Martinez, J.-L., Gerin, S., Merienne, F., Kemeny, A. Software assembly and open standards for driving simulation. *Proceedings of the Driving simulation conference Europe 2010*. 99-108 (2010).
19. Dalton, B.H., Behm, D.G. Effects of noise and music on human and task performance: A systematic review. *Occupational Ergonomics*. **7**, 143-152 (2007).
20. Mayer, J.D., Gaschke, Y.N. Brief Mood Introspection Scale (BMIS). *Psychology*. **19** (3), 1995-1995, doi: 10.1037/0022-3514.55.1.102 (2001).
21. Niedenthal, P.M., Dalle, N. Le mariage de mon meilleur ami: Emotional response categorization and naturally induced emotions. *European Journal of Social Psychology*. **31** (6), 737-742, doi: 10.1002/ejsp.66 (2001).
22. Dalle, N., Niedenthal, P.M. La réorganisation de l'espace conceptuel au cours des états émotionnels. *Annee Psychologique*. **103** (4), 585-616, doi: 10.3406/psy.2003.29653 (2003).
23. Navarro, J., Reynaud, E., Osiurak, F. Neuroergonomics of car driving: A critical meta-analysis of neuroimaging data on the human brain behind the wheel. *Neuroscience & Biobehavioral Reviews*. **95**, 464-479, doi: 10.1016/J.NEUBIOREV.2018.10.016 (2018).
24. Ünal, A.B., de Waard, D., Epstude, K., Steg, L. Driving with music: Effects on arousal and performance. *Transportation Research Part F: Traffic Psychology and Behaviour*. **21**, 52-65, doi: 10.1016/j.trf.2013.09.004 (2013).
25. Navarro, J., Osiurak, F., Reynaud, E. Does the Tempo of Music Impact Human Behavior Behind the Wheel? *Human Factors*. **60** (4), 556-574, doi: 10.1177/0018720818760901 (2018).
26. Brackstone, M., Mcdonald, M. Car-following : a historical review. *Transportation Research Part F: Traffic Psychology and Behaviour*. **2**, 181-196 (2000).
27. Chapman, P.R., Underwood, G. Visual search of driving situations: Danger and experience. *Perception*. **27** (8), 951-964, doi: 10.1068/p270951 (1998).
28. Russell, J.A. A Circumplex Model of Affect. *Journal of Personality and Social Psychology*. **39** (6), 1161-1178, doi: 10.1037/h0077714 (1980).
29. Russell, J.A. Core affect and the psychological construction of emotion. *Psychological review*. **110** (1), 145-72, doi: 10.1037/0033-295X.110.1.145 (2003).
30. Posner, J., Russell, J.A., Peterson, B.S. The circumplex model of affect: an integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and psychopathology*. **17** (3), 715-34, doi: 10.1017/S0954579405050340

(2005).
31. Feldman Barrett, L., Russell, J.A. Independence and Bipolarity in the Structure of Current Affect. *Journal of Personality and Social Psychology*. **74** (4), 967‑984, doi: 10.1037/0022-3514.74.4.967 (1998).
32. Caird, J.K., Johnston, K.A., Willness, C.R., Asbridge, M., Steel, P. A meta-analysis of the effects of texting on driving. *Accident Analysis and Prevention*. **71**, 311‑318, doi: 10.1016/j.aap.2014.06.005 (2014).
33. He, J., Becic, E. Mind Wandering Behind the Wheel : Performance and Oculomotor Correlates. doi: 10.1177/0018720810391530.Copyright (2009).
34. Navarro, J., François, M., Mars, F. Obstacle avoidance under automated steering: Impact on driving and gaze behaviours. *Transportation Research Part F: Traffic Psychology and Behaviour*. **43**, 315‑324, doi: 10.1016/j.trf.2016.09.007 (2016).
35. Navarro, J., Yousfi, E., Deniel, J., Jallais, C., Bueno, M., Fort, A. The impact of false warnings on partial and full lane departure warnings effectiveness and acceptance in car driving. *Ergonomics*. **59** (12), 1553‑1564, doi: 10.1080/00140139.2016.1158323 (2016).
36. Navarro, J., Deniel, J., Yousfi, E., Jallais, C., Bueno, M., Fort, A. Influence of lane departure warnings onset and reliability on car drivers' behaviors. *Applied Ergonomics*. **59**, 123‑131, doi: 10.1016/j.apergo.2016.08.010 (2017).
37. Navarro, J. Human–machine interaction theories and lane departure warnings. *Theoretical Issues in Ergonomics Science*. **18** (6), 519‑547, doi: 10.1080/1463922X.2016.1243274 (2017).

QUESTIONNAIRE

Cette liste contient 16 adjectifs qui font référence à différents états émotionnels. Pour chacun d'eux, vous devez entourer le symbole qui correspond au mieux, à l'état que vous ressentez en ce moment. Vous pouvez graduer vos réponses en fonction de l'intensité émotionnelle que vous ressentez actuellement.

Si vous ne ressentez pas du tout l'état mentionné, entourez XX
Si vous ressentez un peu cet état, entourez X
Si vous ressentez un peu plus cet état, entourez V
Si vous ressentez tout à fait cet état, entourez VV

	pas du tout			***tout à fait***
1. Dynamique	XX	X	V	VV
2. Heureux	XX	X	V	VV
3. Triste	XX	X	V	VV
4. Fatigué	XX	X	V	VV
5. Bienveillant	XX	X	V	VV
6. Content	XX	X	V	VV
7. Mélancolique	XX	X	V	VV
8. Excité	XX	X	V	VV
9. Épuisé	XX	X	V	VV
10. Grincheux	XX	X	V	VV
11. Énergique	XX	X	V	VV
12. Nerveux	XX	X	V	VV
13. Calme	XX	X	V	VV
14. Affectueux	XX	X	V	VV
15. Agacé	XX	X	V	VV
16. Vif	XX	X	V	VV

Experimental set up