Impact of Music Tempo on Simulated Driving Performance

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ABSTRACT

It is known that drivers often listen to music when they are in their vehicle. Listening to music while driving can impact drivers' behaviours in several ways, through emotion induction or arousal changes for instance. It has already been shown that various musical tracks with different tempos (i.e. the music pace) can impair drivers' performances (Brodsky, 2002). The current study focused on the impact of music tempo on vehicular control by using the same music track played at different tempos. Four experimental conditions associated with four different versions of the same track, differing only by their tempos, have been used while participants had to follow a lead vehicle and then drive with no particular constraints. Participants had to drive in a simulated environment without music, with the music track of their choice, with the music of their choice but with a modified tempo (+10% of the regular tempo and -10% of the regular tempo). Results indicated that the music tempo slightly changed the level of arousal of participants as observed through heart rate and subjective questionnaires data. However these changes in the arousal level did not translate into driving behaviours modifications (i.e. inter-vehicle time while following a lead vehicle and speed in free driving context).

Keywords: Music, Driving, Tempo, Driving Behaviour, Arousal.

INTRODUCTION

Playing and listening to music have always been an essential part of human culture. It is known that people often listen to music while driving their vehicle either for professional or recreational purposes. It is even the first self-declared music listening place before listening to music alone at home, while exercising or hanging out with friends (Rentfrow & Gosling, 2003). About 75% of drivers listen to music or to the radio while driving (Dibben & Williamson, 2007). Because in our modern societies driving is a daily activity for most people, it comes with no surprise that several authors intended to study how these two activities (listening to music and driving a vehicle) can affect each other. More precisely, these studies focused on the potential impact of music listening on driving performances (e.g. Bellinger, Budde, Machida, Richardson, & Berg, 2009; Brodsky & Slor, 2013; Dalton, Behm, & Kibele, 2007; Dibben & Williamson, 2007; Nelson & Nilsson, 1990; Pecher, Lemercier, & Cellier, 2009; Ünal, Steg, & Epstude, 2012; Ünal, de Waard, Epstude, & Steg, 2013; Van der Zwaag & al., 2012).

Music can be a subject of study on its own but it can also be studied as "background music" that is to say listening to music while performing another task in parallel. In many cases, such as travelling on public transport, shopping,

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eating at a restaurant or driving for instance, music listening is carried out as a background activity. The influence of background music on the main activity can be very different depending on both the music and the activity considered. While driving, background music has been shown neutral or positive in some cases but negative in some other cases. On the one hand, it was found no music effects on lateral position, speed and reactions to hazardous incidents (Hatfield & Chamberlain, 2008). Furthermore, it was also found that music listening did not impair driving performance and could even help drivers in some situations requiring sustained attention such as car following (Ünal & al., 2012) for instance. On the other hand when drivers were exposed to high volume background music, driving behaviours were impaired (Dalton, Behm and Kibele, 2007). Consequently it seems that the effects of background music on driving is a tricky question, presumably sensitive to several factors related to both driving and music and probably interacting with each other.

Music itself is a complex combination of interacting properties such as tempo, rhythm, mode, pitch and harmony played at a given intensity. Therefore listening to music behind the wheel can affect driving behaviour in several ways. Besides the distraction of drivers interacting with the radio player for instance (Young & Salmon, 2012), music is known to be an emotional inductor that might impair driving performances (Pêcher, Lemercier & Cellier, 2009).

In the present experiment we decided to focus on one of the dimensions of background music: the tempo. The tempo of a music track can be defined as its speed or pace (expressed in beats per minute or BPM). The tempo is considered as a crucial element of most musical compositions. Previous results on the effect of different music tracks associated with different tempos have been reported (Brodsky, 2002). Music tracks with faster tempos led to an increased spontaneous speed, and raised both the number of lane crossings and disregarded red traffic lights in a simulated driving environment. Brodsky classified music tempo in three categories: slow tempo for music tracks ranging from 40 to 70 BPM, moderate tempo for tracks ranging from 85 to110 BPM, and fast tempo for music ranging from 120 to 140 BPM. The main criticism that can be made to Brodsky's experiment is that the manipulation of tempo was obtained through the use of different music tracks. Indeed, Brodsky manipulated tempo by selecting different music tracks from the three categories defined earlier. As a consequence, the observed effects attributed to tempo can also be partly attributed to other music properties and to emotions induced by the different tracks.

The current study was designed to assess the impact of music tempo on vehicular control, using the same music track under different tempo conditions. Four experimental conditions associated with four different versions of the same track, differing only by their tempos, have been used while participants had to follow a lead vehicle at a given distance and then drive with no particular constraints. Participants had to drive without music, with the music track of their choice, with the music of their choice but with a modified tempo (+10% of the regular tempo and -10% of the regular tempo).

Following Kahneman (1973), it was hypothesized that, with an increased tempo, drivers' arousal will increase, leading drivers to be more reactive and therefore more able to maintain the distance with the leading vehicle. Therefore in the case of this simple following task, or free driving, an increase of the tempo is expected to improve performance. The opposite is expected with a decreased musical tempo.

METHOD

Participants

Twenty-four participants volunteered for the experiment. Participants were aged from 18 to 40 years old (22 years old ± 4.4 years) and received their driving licence from 0.2 to 22 years (3.7 years ± 4.5) before the experiment. They drove between 1000 and 27 000 kilometers per year (9075 km ± 8566). The experiment received authorisation from the local ethics committee.

Musical background

Prior to the experiment participants were asked to bring their current preferred music track. The software Audacity® (http://audacity.sourceforge.net/) has been used to play the music track for the duration of each driving session and to modify the tempo of the music. Musical tempo modification has been obtained without any pitch modification, as allowed by the SoundTouch library from Audacity®. Participants faced four auditory backgrounds in a randomized order: (1) No Music - NM- (2) Music without modification -M- (3) Music with +10 % of the regular tempo -M +10- (4) Music with -10 % of the regular tempo -M -10-.

Because music intensity is capable of modifying driving performances (Dalton & Behm, 2007), the intensity of the music was fixed at 75 dB for all auditory backgrounds except for the NM condition.

Procedure

After completion of the consent form, participants took place in front of a driving simulator. The driving scene was played on a 19 inches screen, steering wheel and pedals Logitech G27® were used to control the simulated vehicle. The open-source OpenSD2S software (Institut Image – Le2i/CNRS, ENSAM & Renault) was used for driving simulation. The same driving scenario was used for all four auditory conditions plus a training scenario prior to the proper start of the experiment. The driving scenario was composed of two phases both happening in a similar environment, consisting in a two-lane road with no traffic. During the first phase, participants had to follow a lead vehicle at a 40 meters distance. This lead vehicle (a blue Subaru Impreza) decelerated and accelerated once and then parked on the right side of the road after two and a half-minute of driving. At that time participants had to overtake the lead vehicle and to complete phase two of the scenario by driving with no constraints for about thirty seconds. Prior to the experiment participants were told to respect a speed limit set at 90 Kilometers Per Hour or KPH (i.e. the usual speed limit on two-lane roads in France). Each participant carried out the four driving conditions (NM, M, M+10, M-10).

Data analysis

Three different types of data were collected and analyzed. First of all, the heart rate average and standard deviation were computed for each experimental condition (Biopac® equipment and Acqknowledge® software). Then, the subjective emotional state was collected after each experimental condition using the Brief Mood Introspection Scale (BMIS scale, Mayer and Gaschke, 1988). Finally, driving data were recorded. The Inter-Vehicle Time (ITV) between the lead vehicle and the driven vehicle in phase 1 and the driven vehicle mean speed in phase 2, were then calculated from driving data.

Within-participants ANOVAs were used for statistical analysis. The level of significance of $p < .05$ was used for all statistics. p values between .05 and .1 were considered as a trend. For post-hoc analysis the LSD of Fisher was used in all cases.

RESULTS

Heart rate

Due to recording problems, the data from five participants were unusable and therefore not included in the following heart rate analyses.

Participants mean heart rate was significantly affected by the musical background $F(3, 51)=4.3$, $p< .01$; see Figure 1. The mean heart rate in the NM condition was significantly different from the mean heart rate in the M +10, M -10 conditions ($p< .05$) and tended to differ from the M condition ($p< .1$). Besides, still for the mean heart rate, the M condition tended to differ from the M +10 condition ($p< .1$). To sum up, the presence of music increased the mean heart rate compared to the no-music condition. In addition, the tempo sped up by 10% tended to increase the mean heart rate compared to music at its regular pace.

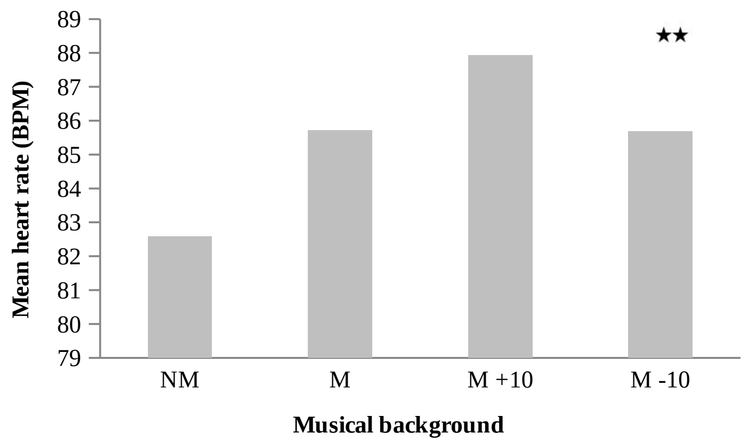

Figure 1. Mean heart rate in the four musical backgrounds in beats per minute.
Error bars represent standard errors.

The heart rate standard deviation was not significantly modified by the musical background F(3, 51)=0.9, NS; see Figure 2.

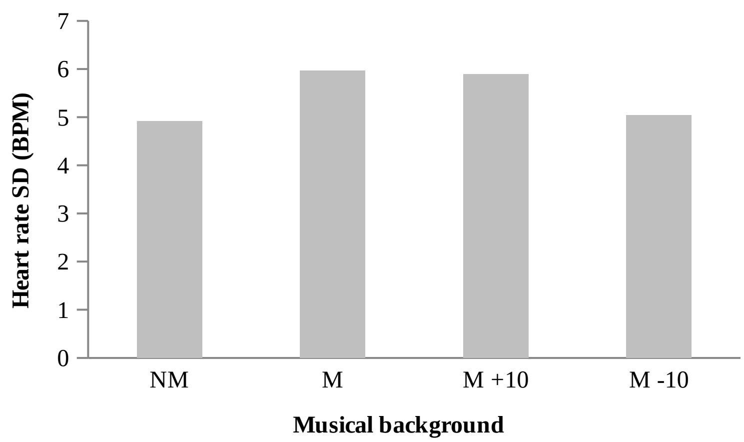

Figure 2. Heart rate standard deviation in the four musical backgrounds in beats per minute.
Error bars represent standard errors.

BMIS

The arousal-calm (Figure 3) and the pleasant-unpleasant (Figure 4) dimensions scores, as assessed by the Brief Mood Introspection Scale (BMIS), were analysed.

Arousal-calm dimension

The musical background significantly affected the level of arousal F(3, 69)=7.7, p<.001. Post-hoc analyses revealed that NM background differed from all other musical backgrounds (p< .05). In addition M +10 background tended to differ from both M and M -10 (p< .1) backgrounds.

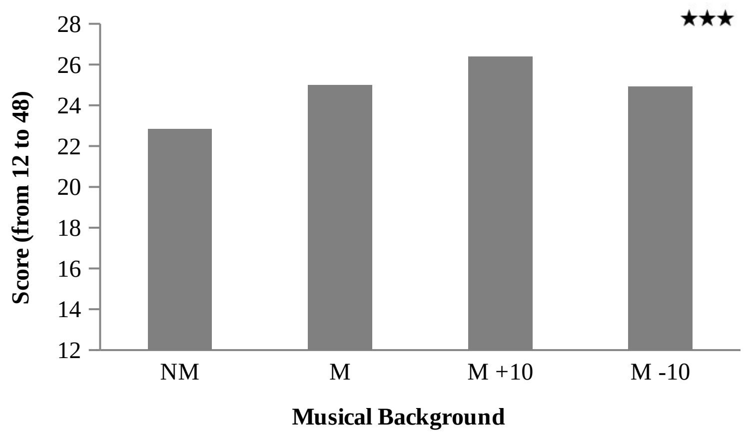

Figure 3. Arousal-calm dimension score from 12 to 48. The higher the score is, the higher is the arousal.
Error bars represent standard errors.

Pleasant-unpleasant dimension

The musical background significantly affected the level of pleasantness F(3, 69)=2.8, p<.05. Post-hoc analyses revealed that NM background differed from M and M +10 backgrounds (p< .05).

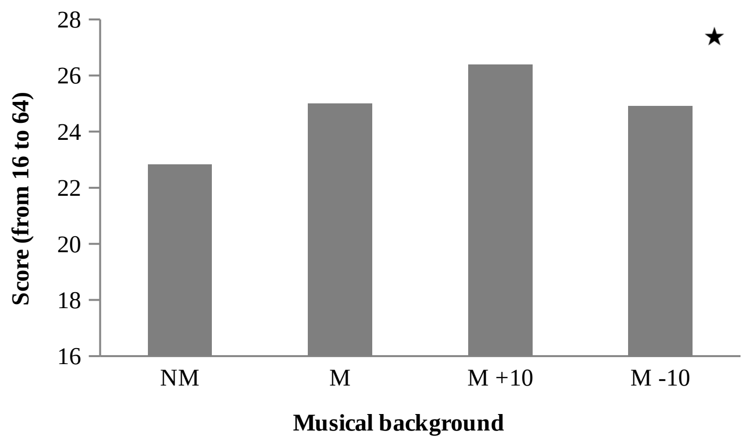

Figure 4. Pleasant-unpleasant dimension score from 16 to 64. The higher the score is, the more pleasant the participant felt.
Error bars represent standard errors.

Driving data

Global analyses

Statistical analyses did not reveal any significant effect of the musical background neither for IVT (F(3, 69)=1.9, NS; Figure 5), nor for the mean spontaneous speed (F(3, 69)=0.6, NS; Figure 6).

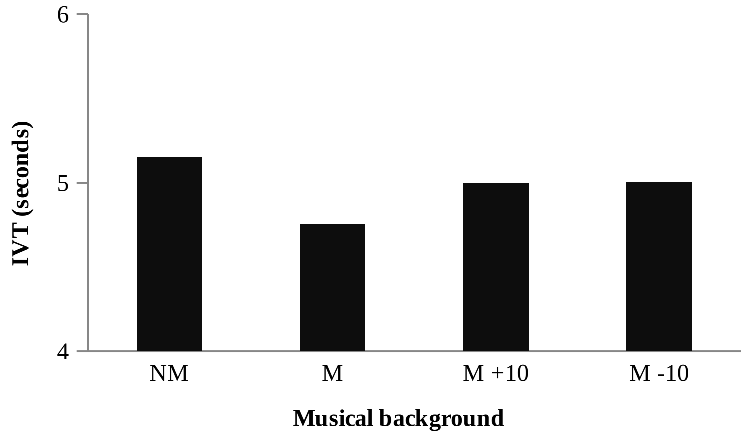

Figure 5. Mean Inter-vehicle Time (IVT) per musical background in seconds.
Error bars represent standard errors.

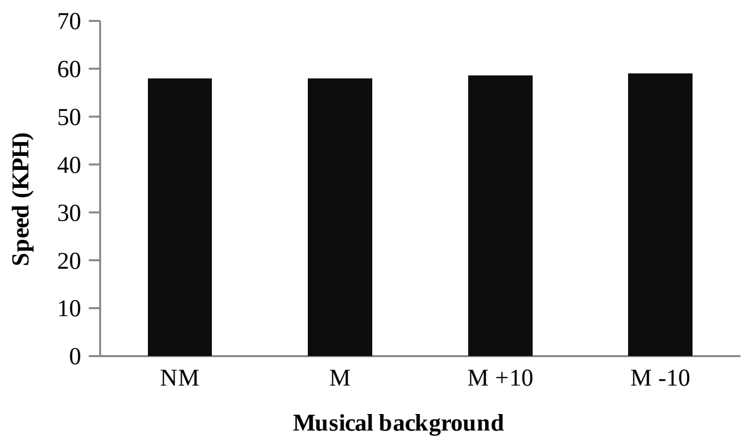

Figure 6. Mean speed per musical background in KPH.
Error bars represent standard errors.

Detailed analyses

To get a clearer picture of the potential impact of musical background on driving performances, analyses were carried out specifically during the acceleration and deceleration phases of the lead vehicle. The IVT and the number of steering wheel reversals (i.e. number of steering wheel direction changes) were computed. Statistical analysis did not reveal any significant effect neither on the acceleration nor on the deceleration phase, for every variable (IVT or steering wheel reversals) considered.

DISCUSSION

Consistent results from heart rate averages and the arousal-calm dimension scores of the BMIS indicated that the presence of background music modified the participants' level of arousal. Indeed the mean heart rate and the level of subjective arousal without music almost always significantly differed from all musical backgrounds. However, the slight changes of music tempo (plus or minus 10% from the original music track tempo) only tended to modify arousal. This trend was observed for music without any tempo modification compared to music sped up by 10%, when looking at the mean heart rates and BMIS arousal scale. Only the BMIS arousal scale tended to indicate that music sped up by 10% increased the level of arousal more than music slowed down by 10%. The observed changes in terms of arousal level did not transfer into any impairments or improvements of driving performances. Both Inter-Vehicle Time (IVT) during the lead vehicle following task, and spontaneous speed in the free driving section were not significantly modified across the four musical backgrounds.

It is undeniable that music might impact people arousal and emotions whatever the country and the culture. Nevertheless, not all individuals are affected the same way by music. Moreover, not all individuals respond the same way to a given music track. Correlations between musical tastes and several personality dimensions have even been shown (Rentfrow & Gosling, 2003). As a consequence, each participant should elect his own musical background in order to ensure a positive impact of the music. This was the choice made in this experiment, where participants brought their own current preferred music track. BMIS questionnaires pointed out that when the musical tracks of the participants were played, they felt more pleased compared to the no-music background. Music track tempo modifications did not change significantly the level of pleasantness. Therefore, it seems that offering participants the opportunity to elect their own musical track was a good choice because it affected their mood consistently in all musical conditions.

Giving participants the opportunity to select their own musical track resulted in tempos ranging from 76 to 172 beats per minute (mean 115 BPM ± 23) before tempo modifications. Because the original tempo was not the same depending on music tracks, tempo modifications (plus or minus 10%) might not have the exact same effects on arousal and driving. In the music plus 10%, background tempos ranged from 83 to 190 (mean 127 BPM ± 26) and in the music minus 10%, background tempos ranged from 68 to 155 (mean 104 BPM ± 21). For comparison Brodsky (2002) used slow tempo tracks ranging from 40 to 70 BPM, moderate tempo tracks ranging from 85 to 110 BPM, and fast tracks ranging from 120 to 140 BPM. In Brodsky's experiment participants had to choose between a few pre-selected musical tracks. When averaged for all participants, all musical backgrounds used in the current experiment were included in a 104-127 BPM interval. These tempos only cover a small range of the large variety of tempos (from 40 to 140 BPM) used by Brodsky (2002).

Even if Brodsky did not observe any significant changes in the heart rate across the different musical condition, contrary to what was found in the current experiment, increases in spontaneous speed, number of lane crossings and disregarded red traffic lights were reported. The current experiment focused on the impact of music on vehicle control (mostly longitudinal through IVT and spontaneous speed). Possibly because of the much smaller tempo variation across conditions as compared to the ones used by Brodsky, the results on spontaneous speed reported were not reproduced in the current study. Brodsky found an almost linear increase in spontaneous speed from slow tempo tracks (mean speed about 132 KPH) through moderate tempo tracks (mean speed about 136 KPH) to fast tempo tracks (mean speed about 140 KPH). It must be noted that these speeds are more than twice the ones recorded in the current study (slightly below 60 KPH). The average spontaneous speeds reported by Brodsky are not realistic in a combined urban and rural environment (the Chicago ring simulated environment) with speed limits set at 50 KPH for municipal road sections and at about 105 KPH for interstate highway. The very high spontaneous speeds obtained by Brodsky compared to speed limits should invite to consider with caution the variation across musical conditions reported.

Based on the data from our experiment it is not possible to conclude that the music tempo (of a same track) is not impacting driving performances because the differences between musical backgrounds were possibly not big enough. It is likely that music tempo is affecting the level of arousal of drivers: the faster the tempo is, the higher the arousal level is. However, the differences observed in the current study are quite small and elicited only a statistical tendency in the results. This is possibly why the auditory background has not significantly affected drivers' performances. The next step is to collect data with larger differences in terms of tempo between musical background conditions.

CONCLUSION

A slight tempo modification (±10%) of the participants' own music track caused slight changes in arousal as observed through questionnaires and heart rate analysis. However these changes did not translate into significantly different driving behaviours in the current experiment. Further studies are needed before a definitive conclusion can be drawn on the impact of music tempo on driving performances. In addition, driving context, music rhythm, music intensity, and emotions inducted through music are some of the main factors that probably combine and impact driving behaviours. Further research is also required to investigate how these different variables influence driving behaviours, for a full understanding of such a popular activity as listening to music while driving.

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