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The influence of music on mood and performance while driving

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Mood can influence our everyday behaviour and people often seek to reinforce, or to alter their mood, for example by turning on music. Music listening while driving is a popular activity. However, little is known about the impact of music listening while driving on physiological state and driving performance. In the present experiment, it was investigated whether individually selected music can induce mood and maintain moods during a simulated drive. In addition, effects of positive, negative, and no music on driving behaviour and physiological measures were assessed for normal and high cognitive demanding rides. Subjective mood ratings indicated that music successfully maintained mood while driving. Narrow lane width drives increased task demand as shown in effort ratings and increased swerving. Furthermore, respiration rate was lower during music listening compared to rides without music, while no effects of music were found on heart rate. Overall, the current study demonstrates that music listening in car influences the experienced mood while driving, which in turn can impact driving behaviour.

Practitioners Summary: Even though it is a popular activity, little is known about the impact of music while driving on physiological state and performance. We examined whether music can induce moods during high and low simulated drives. The current study demonstrates that in car music listening influences mood which in turn can impact driving behaviour. The current study shows that listening to music can positively impact mood while driving, which can be used to affect state and safe behaviour. Additionally, driving performance in high demand situations is not negatively affected by music.

Keywords: music mood induction; demand; simulated drive; respiration rate; heart rate; driving behaviour

1. Introduction

In Western society, music listening has become a frequent activity in the background of almost any activity (DeNora 2000, North and Hargreaves 2008). Music research has now started to focus on music listening in these specific everyday life situations to improve the understanding of how music can influence personal experiences and behaviour (DeNora 2003, Juslin and Sloboda 2010). Driving is one of the most popular music listening situational contexts. While driving, people listen to music to attain enjoyment or to feel engaged when driving in solitude (DeNora 2000, Walsh 2010). It also is suggested that music listening distracts from driving and can therefore influence safety (Brodsky 2002). Although the impact of music on driving performance has been given some attention (Dibben and Williamson 2007), its impact on mood and physiological measures has not. Neither has a distinction been made between the respective impacts of the specific types of music such as positive and negative valence music. In the current article, these

relationships between music valence and driving demand on mood, physiological measures, and driving performance are studied.

1.1. Music listening

The potential of music to influence mood is described as one of the most important functions of music (Juslin and Sloboda 2010, Van der Zwaag and Westerink 2010, Van der Zwaag *et al.* 2011). Although music is known to influence mood, it is still under discussion whether people perceive the expressed state within the music (cognitivist view) or whether music can actually induce moods in listeners (emotivists view) (Kivy 1989, 1990). Evidence of the fact that music induces emotions is for example found by Kastner and Crowder (1990) who showed that major mode music is perceived as more happy compared to minor mode music. Furthermore, fast tempo music has consistently shown to increase arousal levels compared to slow tempo music (Krumhansl 1997, Van der Zwaag *et al.* 2011).

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Support for the emotivist position of the influence of music on emotion comes from the growing body of evidence that music can influence physiological responses and thus body state (for an overview see Hodges (2010)). Heart rate and respiration rate (RR) are the most frequently investigated psycho-physiological responses to music (Hodges 2010). The majority of studies in the music literature have found that arousing music increases heart rate compared to low arousing music (DeJong *et al.* 1973, Knight and Rickard 2001). Still, others have found that any music, both low and high arousing, increases heart rate (Krumhansl 1997, Iwanaga and Moroki 1999, Rickard 2004). RR is found to increase in high arousing compared to sedative music as well (Iwanaga and Moroki 1999, Krumhansl 1997, Nyklíček *et al.* 1997 Gomez and Danuser 2004). Again, in other studies no difference in RR while listening to different types of music was found (Davis 1992, Van der Zwaag and Westerink 2011a). Hence, inconsistent results are found on heart rate and RR responses to music listening. Note further that these latter studies presented music listening as main task, and thus not as in the background of a concurrent activity, such as driving. Still, it is implied that mood can remain when music is played in the background of a concurrent activity, as Van der Zwaag and Westerink (2011b) showed the persistence of musically induced moods in the background of a distracting task.

Several explanations can be given for the inconsistent results found for the influence of music on physiological measures. A first explanation comes from the fact that studied physiological measures are affected by regulatory effects in the autonomic nervous system (ANS) which is primarily responsible for keeping homeostasis (Cacioppo *et al.* 2000b). As a result, physiological responses are not solely influenced by emotional state via, for example, music listening but additionally via physical activity, cognitive demand, and other psychological constructs (Cacioppo *et al.* 2000b, Van den Broek and Westerink 2009). Hence, the situational context should be taken into account in interpreting physiological responses to music listening. A second explanation can be found in the fact that most studies in music research differ to a great extent on important methodological aspects, such as the song selection method and the duration of the music presentation. For example, Van der Zwaag and Westerink (2011a) showed that the physiological response patterns to positive and negative music mood induction start to differentiate after an average of 4 min. Hence, the physiological responses to music listening in studies presenting relatively short music excerpts cannot be compared to studies inducing moods with music over longer periods. For the study

of physiological responses to music, awareness of these methodological aspects is important, as is the perspective to always describe the impact of music to emotions in relation with personal and situational context (Blacking 1973, Saarikallio and Erkkilä 2007, North and Hargreaves 2008, Sloboda and Juslin 2010).

1.2. Music while driving

Music can be beneficial while driving as, for example, the mood-arousal hypothesis predicts that in cases of boredom and drowsiness music can lead to a more optimal arousal level which could benefit driving performance (North and Hargreaves 2008, Shek and Schubert 2009). However, following the distraction hypothesis, music can also take attention away from the driver (Shek and Schubert 2009). This distracting effect of music on driving can be disadvantageous when it decreases safety in case high arousing music is played during high demand road situations (Dibben and Williamson 2007). On the contrary, Wiesenthal *et al.* (2000) showed that one's favourite music alleviates stress during high congestion drives and found higher stress levels when comparing no music to favourite music during high congestion drives. Furthermore, it is shown that driver aggression can be tempered with favourite music compared to no music in high demanding rides (Wiesenthal *et al.* 2003).

Explanations for the effects of music listening while performing a concurrent task such as driving often focus on processing capacity in service of the primary task (North and Hargreaves 1999, Dalton and Behm 2007, Pêcher *et al.* 2009) and assume that listening to music may be arousing and therefore requires mental resources. Following the information–distraction approach, music adds additional irrelevant stimuli to a task which leads to increased cognitive load and thus can impact task performance (Konečni 1982, North and Hargreaves 1999, Recarte and Nunes 2000). Consequently, the more attention a particular music requires the more it competes for processing resources with the primary task of, for example, driving. To illustrate, North and Hargreaves (1999) manipulated cognitive load of participants by exposing them to low or high arousing music by varying tempo and volume in a driving game. They found that high arousing music resulted in worse racing performance defined as slower lap times, while the quickest lap times were recorded when listening to low arousing music. Interestingly, they also found a connection between task demand and music liking, and concluded that competition for processing resources caused participants to dislike music. Pêcher *et al.* (2009) mentioned that post-experiment interviews revealed that drivers found happy music the most disturbing

and, combined with behavioural data, took this as support to conclude that listening to happy music resulted in deteriorated driving performance.

The impact of in-vehicle music listening on driving speed depends on the road situational context. Reducing speed is found to be used as a compensatory reaction when faced with high load situations, namely it enables the driver to maintain safety margins by decreasing required reaction times (Summala 2005). Furthermore, as mentioned above it can be expected that drivers allocate more attention, and thus mental resources, to positive music which could result in detrimental effects on vehicular control or in a compensatory reaction such as slowing down.

Because task performance and music listening might compete for the same mental resources, the impact of musically evoked cognitive demand on performance might be dependent on the cognitive demand of a concurrent task (Konečni 1982, North and Hargreaves 1999). In low demand drive situations, there is less competition for attentional space. Hence, it is likely that mental resources can more easily be divided between listening to music and driving as the limits of mental resources are not reached. Therefore, listening to music will not impact driving performance in these low-demand situations. As lane width is known to influence drivers workload, this variable could be used to manipulate primary task demands when studying the relation between listening to positively and negatively rated music. Results reported in the literature show that when driving in narrow lanes, less manoeuvring space is available for the driver, and more attention is required to prevent driving errors such as drifting out of the driving lane and to maintain personal safety margins (De Waard *et al.* 1995, Dijksterhuis *et al.* 2011). This results in smaller deviations from the driver's preferred lateral position (LP) on the road (De Waard *et al.* 1995, Dijksterhuis *et al.* 2011) and a compensatory speed reduction (Godley *et al.* 2004). In terms of physiological responses, higher demand situations would lead to increased heart rate and RR.

1.3. Expectations

The aim of the current study was twofold. First, we wanted to investigate whether musically induced positive and negative moods persist during low and high demand drives. Moreover, we investigated whether the presence of positive compared to negative music influences the resources mobilised, as reflected in the amount of effort invested while driving. We expected that positive and negative valence can be successfully induced during music mood induction (Van der Zwaag and Westerink 2010, 2011a).

Furthermore, based on Van der Zwaag and Westerink (2011b), we expect that positive and negative music mood induction will persist while driving. Furthermore, we expect that the presence of positive or negative moods will remain during high demand drives.

Secondly, the influence of musically induced mood on driving performance in high (narrow lane width) and low (wide lane width) demanding drives was investigated. Hence, lane width was used to further investigate the relation between listening to positively and negatively rated music and primary task demands. First of all, while driving, we expected increased RRs and heart rate during high compared to low demanding drives. In accordance with Dijksterhuis *et al.* (2011), less swerving (i.e. reduced variation in LP) was expected in narrow lanes. Furthermore, we expected that lane width reduction would lower the speed to compensate for the higher amount of resources allocated in the more demanding drive (De Waard *et al.* 1995, Godley *et al.* 2004). We expected that music would solely influence driving performance in high demand drives, as in those conditions music competes with the limited amount of mental resources available.

2. Method

2.1. Participants

The study had been approved by the local ethics committee and informed consent was obtained from all participants. Nineteen participants, 13 men and 6 women, were paid 45 Euros for participating. Age ranged from 22 to 44 years (mean = 27.5; SD = 5.2) and participants had held their driving licence for 4 to 22 years (mean = 8.8; SD = 4.9). Self reported total mileage driven ranged from 6000 to 700,000 km (median = 45,000; inter-quartile range (IQR) = 77,500 km) and current yearly mileage ranged from 1500 to 6000 km (median = 7000; IQR = 5000).

2.2. Design

Three music conditions were included: positive music, negative music and no music (which was included as an extra control condition). In addition, two levels of lane width (wide 3.00 m or narrow 2.50 m) were created in the driving simulator, corresponding to low and high demand drives, respectively (Dijksterhuis *et al.* 2011). Participants completed four sessions on separate days: one introduction session and three experimental sessions. In each experimental session, one music level was presented and both lane widths were used. This resulted in a within-subject design including two

repeated-measures factors: music (3) and lane width (2). The orders of both the music and lane width factors were counterbalanced among participants.

2.3. Music stimuli selection

Because music preference is highly personal (Hargreaves and North 2010), songs used as stimuli were selected individually. To do so, participants completed an introductory session prior to the experimental sessions. In this session, participants rated 60 songs on perceived valence and energy levels on 7-point Likert scales. The participants did not have to listen to the entire song but were encouraged to sample each song for a few moments and at a few locations within the song to get a good impression of the song. The 60 songs included were selected to have a large range of valence and energy values and were selected from a database containing 1800 songs in total. The songs were selected based on energy and valence labels which were acquired by automatic classification of music characteristics into mood labels (Skowronek *et al.* 2006, 2007). The order of the song presentation was randomised over participants.

After participants had finished the ratings, nine songs were selected per participant per music condition (positive/negative) in such a way that valence ratings differed as much as possible between the positive and negative songs while keeping energy ratings as average as possible. Subsequently, three of the selected songs were used for the music mood induction, three songs for the high demand drive, and three songs for the low demand drive. The duration of the three songs was adjusted, using Audacity (Version 1.2.4), to 8 min, keeping the average duration of each song about equal. This was done by cutting the song to about 2.45 min and fading out the new ending of the song.

To check the selected song stimuli on their valence and energy ratings, a repeated-measures ANOVA with music (positive/negative) as within-subject factor on the valence and energy ratings of the selected songs was conducted. Results showed a main effects of Music on both energy and valence ratings: valence $F(1,17) = 231.20$, $p < 0.001$, $\eta^2 = 0.93$; energy $F(1,17) = 16.04$, $p < 0.001$, $\eta^2 = 0.49$. This confirmed that the selected song stimuli for the two Music conditions were significantly different from each other in valence and energy. The positive songs showed higher valence and energy ratings compared to the negative songs; positive songs mean (SE) valence $M = 5.8$ (0.17), energy $M = 4.7$ (0.20), negative songs valence $M = 2.3$ (1.4), energy $M = 3.3$ (0.26), on scales running from 1 to 7.

2.4. Simulator and driving conditions

The study was conducted using a ST Software© driving simulator. This simulator consists of a fixed-base vehicle mock up with functional steering wheel, indicators, and pedals. The simulator was surrounded by three 32" diagonal plasma screens. Each screen provided a 70° view, leading to a total 210° view. A detailed description of the functionality of the driving simulator used can be found in Van Winsum and Van Wolfelaar (1993).

Participants drove the simulated car (width: 1.65 m) over two sections of uninterrupted two-lane roads (2.50 m or 3.00 m wide lanes), winding through rural scenery, and separated by a small town. Roads in each section consisted mainly of easy curves (about 80%) with a constant radius of 380 m and ranging in length from 120 to 800 m. The road surface was marked on the edges by a continuous line (20 cm wide), in the centre by a broken line (15 cm), and outside the edges a soft shoulder was present. The posted speed limit during the drive was 80 km/h. In addition, a stream of oncoming traffic was introduced with a random interval gap between 2 and 6 s, resulting in 15 passing passenger cars (width: 1.75 m) per minute on average. No vehicles appeared in the participant's driving lane.

2.5. Measures

2.5.1. Subjective ratings

Subjective mood scores of valence (ranging from unpleasant to pleasant) and energy (ranging from tired/without energy to awake/full of energy) and calmness ratings (ranging from tense to calm) were assessed using the UWIST Mood Adjective Checklist (UMACL) (Matthews *et al.* 1990). This UMACL contains eight unipolar items for each dimension, which start with: 'right now I am feeling. . .', and range from 1: 'not at all' to 7: 'very much'.

The rating scale mental effort (RSME) was used to assess mental effort (Zijlstra 1993). The RSME is a unidimensional scale, ranging from 0 to 150, used to rate mental effort. In addition to digits, several effort indications (calibrated anchor points) are visible alongside the scale to further guide rating. Indications start with 'absolutely no effort' (RSME score of 2) and end with 'extreme effort' (RSME score of 112).

2.5.2. Physiology

Physiological measures covered ANS reactions in the cardiovascular and respiratory domain. The Portilab data recorder and its accompanying

sensors were used to record these responses with a sample frequency of 250 Hz (version 1.10, Twente Medical Systems International, Oldenzaal, the Netherlands). Physiological measures were assessed continuously during the experiment. The MATLAB programming environment (2009, The Mathworks, Natick, MA) was used for the pre-processing of the respiration signals.

Cardiovascular measures were recorded using an electrocardiogram (ECG) using three Ag-AgCl electrodes, which were placed following the standard lead II placement (Stern *et al.* 2001). R-peaks in the ECG signal were detected automatically, after amplification and filtering of the signal (Butterworth band pass: 0.5–40 Hz). Subsequently, the distances between successive R peaks, the interbeat intervals (IBI), were calculated.

Respiration was recorded by means of a respiration belt (Respirace™, Twente Medical systems). To obtain the respiration measures, noise was excluded from the raw signal and movement artifacts were reduced by a 0.005–1.0 Hz band pass IIR filter. The amount of respiration cycles per minute indicated the RR (Wientjes 1992, Grossman and Taylor 2007).

2.5.3. Driving parameters

Speed and LP were sampled at 10 Hz. Lateral position is defined as the difference in metres between the centre of the participant's car and the middle of the (right hand) driving lane. Positive LP values correspond to deviations towards the left-hand shoulder and negative values correspond to deviations toward the right-hand shoulder. The sampled LP values were used to calculate mean LP and the standard deviation of LP, i.e. swerving.

2.6. Procedure

Participants were invited four times to the driving simulator facility of the University of Groningen. During the first introductory session, the participants were informed about the experiment, signed an informed consent, drove a 6-min practice drive, and completed the music rating.

During the three subsequent experimental sessions, physiological sensors were attached and participants were seated in the simulator chair. Next, physiological baseline values were acquired in a habituation period during which participants watched a Coral Sea diving movie for 8 min (Piferi *et al.* 2000). Hereafter, participants filled out the UMACL. Then an 8-min music mood induction period started in which the participants were asked to listen to the music. To remain attentive to the music, participants were asked to listen to the music carefully to be able to answer questions regarding the music after the entire experiment. During the control

session in which no music was presented, participants were asked to sit and relax for 8 min. The participants were not informed that mood induction took place during these 8 min, as this could bias the results. After 8 min, the participants filled out the UMACL again.

Next, the first simulated drive began. The participants were instructed to drive as they would normally drive. After approximately 8 min, participants were instructed to park the car and the music was stopped. During this break participants were asked to complete the UMACL questionnaire and the RSME scale. Next up, the second 8-min drive started which only differed from the first drive in lane width. After completing the ride, participants filled out the UMACL and RSME again. The total duration of each experimental session including instructions and attaching and de-attaching the physiological equipment approximated 70 min.

2.7. Data analysis

Data were analysed using SPSS 17 for Windows (SPSS Inc., Chicago, IL) with level of significance at $p < 0.05$ (two-tailed). The data acquired during the music mood induction period were analysed to confirm that successful mood induction took place using a repeated-measures ANOVA with music (positive/negative/no music) as within-subject variable. Furthermore, the data obtained during the drives were analysed to show the effect of the music on driving using a repeated-measures ANOVA with music (positive/negative/no music) and driving demand (wide/narrow) as within-subject variables. Pairwise comparisons were Bonferroni corrected.

3. Results

3.1. Subjective ratings

The reliability of the mood dimensions was determined using the normal and the reverse coded items of the UMACL questions. This rendered Chronbach's alphas for energy of 0.84, valence of 0.89, and calmness of 0.90. Next, to show whether the baseline values were not different from each other between the three music sessions a repeated-measures MANOVA with music (positive/negative/no music) as within-subject factor was conducted on the valence, energy, and calmness ratings obtained directly after the baseline period, i.e. before the music mood induction. Results do not show a significant multivariate effect of music ($F(6,70) = 1.54, p = 0.18, \eta^2 = 0.12$). The baselines ratings were as follows: valence ($M = 5.5, SE = 0.18$), energy ($M = 3.8, SE = 0.13$), and calmness ($M = 6.0, SE = 0.12$). Next, mood reaction scores were obtained by subtracting the values obtained during baseline

from the values obtained during the conditions; either mood induction or the two drives.

A repeated-measures MANOVA, with the within-subject factor of music (positive/negative/no music) was conducted on the subjective valence, energy, and calmness reaction scores obtained after the music mood induction. A significant multivariate effect of music was found ($F(6,70) = 2.51, p = 0.029, \eta^2 = 0.177$). Univariate tests show significant main effects on valence and energy reaction scores during the mood induction (valence: $F(2,36) = 4.21, p = 0.023, \eta^2 = 0.19$, Energy: $F(2,36) = 6.0, p = 0.006, \eta^2 = 0.25$, calmness: $F(2,36) = 2.22, p = 0.12, \eta^2 = 0.11$). Pairwise comparisons show that positive music results in higher valence and energy reaction scores compared to both the negative music (valence $p = 0.042$, energy $p = 0.042$) and the no music conditions (valence $p = 0.024$, energy $p = 0.004$). Figure 1 displays the mean energy and valence ratings obtained after the drives. Average and standard errors in parentheses of the calmness ratings were $-0.25 (0.15)$ for positive music, $-0.71 (0.17)$ for negative music, and $-0.58 (0.15)$ for no music.

Next, a repeated-measures MANOVA with music (positive/negative/no music) and driving demand (wide/narrow) as within-subject factors was conducted on the valence, energy, and calmness reaction scores obtained after the two drives. Results show a marginally significant multivariate effect of music ($F(6,70) = 2.22, p = 0.053, \eta^2 = 0.160$). No significant multivariate effects were found for driving demand ($F(3,16) = 0.82, p = 0.50, \eta^2 = 0.13$) or the music with drive demand interaction ($F(6,70) = 0.42, p = 0.86, \eta^2 = 0.04$). The univariate results for music show significant main effects on valence and energy reaction scores (valence $F(2,36) = 4.33, p = 0.021, \eta^2 = 0.19$;

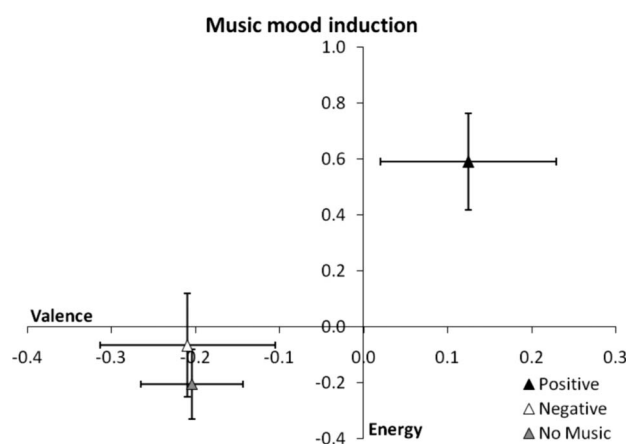


Figure 1. Subjective valence and energy reaction scores provided after the music mood induction. The error bars represent \pm standard error.

energy $F(6,70) = 3.49, p = 0.041, \eta^2 = 0.16$; calmness ($F(2,36) = 2.21, p = 0.124, \eta^2 = 0.11$). Pairwise comparisons of music show marginally higher valence reaction scores ($p = 0.051$) and marginally higher energy reaction scores ($p = 0.095$) during the positive condition compared to the no music condition irrespective of driving demand. Figure 2 shows the mean energy and valence reaction scores obtained after the drives. Average calmness reaction scores were the following: Mean (standard error) positive wide $M = -0.27 (0.14)$, narrow $M = -0.55 (0.18)$, negative wide $M = -0.74 (0.20)$, narrow $M = -0.82 (0.23)$, no music wide $M = -0.76 (0.19)$, narrow $M = -0.87 (0.19)$.

To evaluate the perceived amount of mental effort (RSME scores) during the drives, a repeated-measure ANOVA of music (positive/negative/no music) with driving demand (wide/narrow) as within-subject factors was conducted on the RSME ratings. A significant effect of driving demand was found ($F(1,18) = 9.12, p = 0.007, \eta^2 = 0.34$). Pairwise comparisons of driving demand reveal higher RSME ratings during the narrow drive ($M = 39.37, SE = 5.42$) compared to the wide drive ($M = 33.10, SE = 4.68$). No significant effects of music or the music with driving demand interaction were found; music $F(2,36) = 1.96, p = 0.156, \eta^2 = 0.10$; music with driving demand $F(2,36) = 0.10, p = 0.907, \eta^2 = 0.005$.

3.2. Physiological responses

A repeated-measures MANOVA with music (positive/negative/no music) as within-subject factor was conducted for both the RR and the mean IBI duration obtained during the last 3 min of the baseline period. Results do not show a significant main effect of music

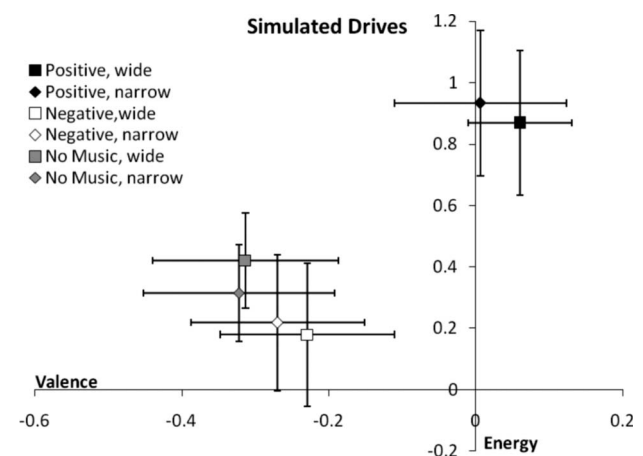


Figure 2. Subjective valence and energy reaction scores provided after the wide and the narrow drives. The error bars represent \pm standard error.

on RR and on mean IBI, indicating that the baseline RRs and IBI durations did not differ for the different sessions; RR $F(2,36) < 1$, $p = 0.54$, $\eta^2 = 0.04$, mean (SE) in breath/min: positive 14.61 (0.95), negative 14.04 (0.73), no music 15.20 (0.76); IBI $F(2,36) = 1.18$, $p = 0.36$, $\eta^2 = 0.62$, mean (standard error) IBI duration in seconds: positive = 0.874 (0.03), negative = 0.846 (0.03), no music = 0.876 (0.03). Next, physiological reaction scores were created by subtracting the average values obtained during the last 4 min of the baseline period with the values obtained during the induction and the drives.

3.2.1. Respiration rate

A repeated-measures ANOVA with music (positive/negative/no music) as within-subject variable was conducted on the reaction scores of the RR obtained during the induction. No significant main effects were found showing the RRs did not differ during the induction period ($F(2,36) < 1$, $p = 0.78$, $\eta^2 = 0.013$), see Figure 3. Subsequently, a repeated-measure ANOVA was conducted with music (positive/negative/no music) with driving demand (wide/narrow) as within-subject factors on the RR. Results show a main effect of music; $F(2,36) = 3.25$, $p = 0.050$, $\eta^2 = 0.153$. Pairwise comparisons show a significantly lower RR during the negative compared to the no music condition ($p = 0.046$) irrespective of driving demand, see also Figure 3. No significant effects of the driving demand or interaction effect of music with driving demand were found.

3.2.2. Cardiovascular measures

A repeated-measures ANOVA with music (positive/negative/no music) as within-subject variable was conducted on the IBI reaction scores of the induction. No significant main effect of Music was found showing

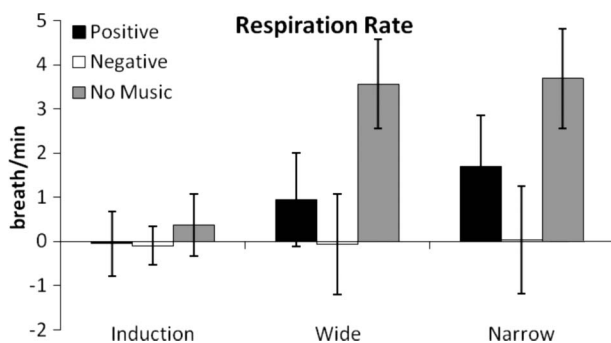


Figure 3. The average respiration rates for induction, the wide, and the narrow drives. The error bars represent ± 1 standard error.

the IBI durations were not different during the induction; $F(2,36) < 1$, $p = 0.40$, $\eta^2 = 0.049$, mean (SE) positive -0.01 (.006), negative -0.008 (0.006), no music -0.001 (0.006). Subsequently, a repeated-measure ANOVA was conducted with music (positive/negative/no music) and driving demand (wide/narrow) as within-subject factors on the average IBI durations obtained during the drives. Results show no significant effect for music or driving demand (all $p > 0.05$) positive mean (Standard Error) = -0.017 (0.009), negative = -0.019 (0.008), no music = -0.022 (0.007), wide drive = -0.018 (0.07), narrow drive = -0.019 (0.07).

3.3. Driving performance

Separate repeated-measures analysis of music (positive/negative/no music) with driving demand (wide/narrow) as within-subject factors was conducted on the mean of the LP, the standard deviation of the lateral position (SDLP, swerving), and the speed. A trend was found for mean LP, and for SDLP a significant main effect of driving demand was found; LP (m) $F(1,17) = 3.51$, $p = 0.082$, $\eta^2 = 0.201$; LP (sd) $F(1,17) = 23.80$, $p < 0.001$, $\eta^2 = 0.583$. During the narrow lane drive, more distance from the centre line is found and the SDLP is smaller compared to the wide lane drive; see also Figures 4 and 5. The results on speed show a marginally significant main effect of music ($F(2,13) = 3.18$, $p = 0.075$, $\eta^2 = 0.329$). Pairwise comparisons show higher speed during the no music condition compared to the positive music condition ($p = 0.023$) irrespective of driving demand; the average speed values are illustrated in Figure 6.

4. Discussion

Music listening is a very popular side-activity while driving. However, the influence of music listening on

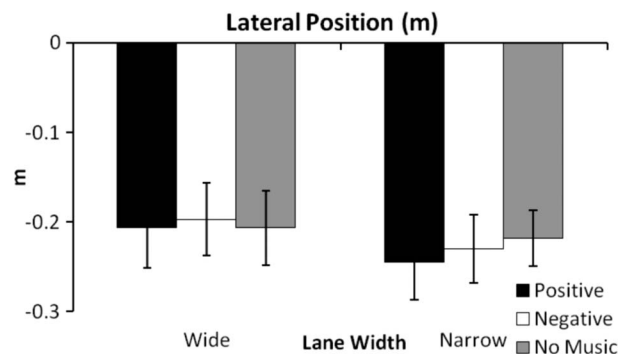


Figure 4. The average lateral position from the centerline of the road, obtained during the wide (3 m) and narrow (2.50 m) drives. The error bars represent ± 1 standard error.

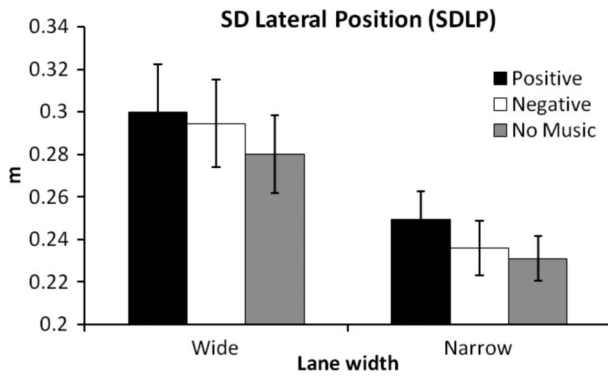


Figure 5. SDLP (standard deviation of the lateral position), i.e. swerving, obtained during the drives on the wide (3 m) and narrow (2.50 m) roads. The error bars represent ± 1 standard error.

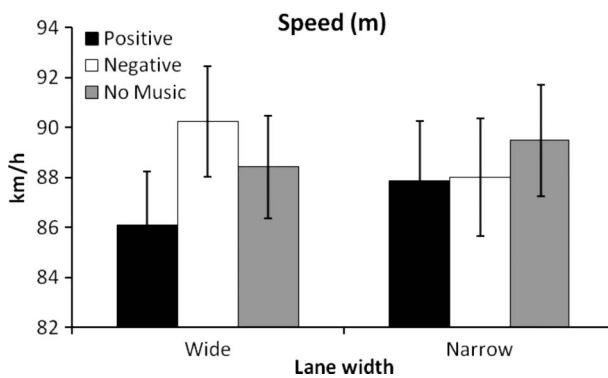


Figure 6. The speed (km/h) during the drive on the wide (3 m) and on the narrow (2.50 m) roads. The error bars represent ± 1 standard error.

the body state and on driving performance is not yet fully understood. In the current study it was investigated whether personally selected positive and negative music influences mood, body state, and driving performance. Results show a successful mood induction by music: the induced moods are congruent with the expected moods based on the song stimuli which were selected per participant (see also Figure 1). Furthermore, music listening as primary activity did not change cardiovascular and respiratory responses. In contrast, lower RRs were found in the conditions where music was presented during drives compared to conditions in where no music was presented at all. Finally, as hypothesised, less swerving was observed in the higher demanding drives irrespective of music presence. Thus, the current findings support that music and driving demand influence mood, physiological state, or driving performance to a certain extent.

4.1. Mood induction through music

In line with the literature, in the two music conditions positive or negative moods were induced with music over 8-min periods while listening to music as the primary task (Gendolla 2000). The condition without music induced an equal mood state comparable with the mood induction with negative music. This may be explained in that the music is known to influence time perception causing the music listening situations being perceived shorter in duration (Cassidy and MacDonald 2010). For instance, MacDonald *et al.* (2003) have shown that waiting in a hospital context with music makes participants less anxious than if they have to wait without music. Hence, a situation in which no music is presented might be perceived as long and boring, thereby inducing a negative mood (Juslin and Sloboda 2010).

In line with previous research, RR and heart rate did not vary between positive and negative mood inductions (Gendolla and Brinkman 2005, Silverstrink and Gendolla 2007; Van der Zwaag and Westerink 2011a). This finding can be explained in that mood does not immediately result in action tendencies and thus not in altered physiological responses (Gendolla 2000). In contrast, it has been shown that for other physiological measures than heart rate and RR, such as skin conductance and facial muscle tension, differentiation between moods during music mood induction can be observed (Cacioppo *et al.* 2000a; Van der Zwaag and Westerink 2011a).

4.2. Effects of music during high and low demand drives

As expected, (subjective) effort invested in driving was higher while driving in the narrow lanes (Dijksterhuis *et al.* 2011). Furthermore, as expected while driving, the induced mood persists in terms of valence and energy ratings irrespective of driving demand and music type. The energy ratings increase during the drive regardless of whether the music was positive or negative, which can be attributed to the execution of a concurrent task while driving. The result confirms previous research findings (Van der Zwaag and Westerink 2011b) and also extends the literature as it indicates that moods induced with music can maintain in concurrence of a task irrespective of task demands.

Listening to negative music compared to no music while driving results in lower RRs irrespective of driving demand. This finding holds even though subjective mood ratings are equal when listening to negative music compared to not listening to music. This implies that music might be used to unconsciously decrease body stress of the driver as RR has been

linked to arousal (Boiten *et al.* 1994, Nyklíček *et al.* 1997, Ritz 2004, Homma and Masaoka 2008). For example, Nyklíček *et al.* (1997) have shown that stimulative music leads to faster RRs. This result emphasises the importance of incorporating physiological measurements as they can uncover findings that would remain unnoticed by subjective ratings (Van den Broek and Westerink 2009).

Driving performance was influenced by both driving demand and the music played during the drive. With regard to driving parameters, the mean LP and the amount of swerving (SDLP) both decreased during high demand drives. Driving in a narrow lane was as expected associated with a decrease in swerving. This confirms that more effort was put into the lane keeping task to deal with decreased lateral margins. Furthermore, this is in accordance to Summala's Multiple Monitor Theory (Summala 2005, 2007), which states that mental load increases when less time is available to maintain safety margins. In a more general sense, these results can be seen as an indication that more effort was invested in the driving task to prevent performance degradation (Hockey 1997, 2003) or that the level of effort was matched to the current task demands (Hancock and Warm 1989, Matthews and Desmond 2002). Furthermore, in contrast to Pêcher *et al.* (2009), in the current study in the no music condition swerving was not decreased, hence music listening did not affect lateral safety. This difference in results can be explained in that Pêcher *et al.* (2009) altered music periods with silent periods of 1 min each. This alteration could distract the driver and therefore decrease swerving while listening to music. The current results thus show a more ecological valid situation and hence more ecologically valid results.

Driving in a narrow lane did not decrease driving speed. This could imply that the high demanding situation was not demanding enough to lead to changes in driving performance. The data do show lower speed during the positive music drives compared to the drives without music. This could be caused by increased engagement in the drive while listening to personally selected positive music which resulted in context appropriate speed choices, instead of having distracting effects (Cassidy and MacDonald 2009). This finding is in line with the increased RRs during the no music condition; faster speed coincides with higher physical effort.

Lastly, the current study did not show an interaction between driving demand and music. This could be explained in several ways: first, the music used in this study might not have demanded much attentional resources because it was moderate instead of high arousing (Cassidy and MacDonald 2009). Listening to music, therefore, did not require more than the

resources still available next to those required for driving, so no real competition for resources resulted. This in line with Beh and Hirst (1999) who showed that high intensity music, which asks for more resources, did decrease performance during high demand conditions in a driving-related task. Second, experienced drivers participated in the study. Therefore, the additional load added by music listening while driving could have been minimal, as the driving task itself can be expected to be mainly automated. Music listening during novice drivers might, however, result in different outcomes. Taken together, these results indicate that music intensity can be an important factor in predicting the influence of music on decreases in driving performance during high demand driving situations.

4.3. Limitations and future research

The song stimuli varied in valence and to a lesser extent in energy levels as well. Note that the selected songs were not the most contrasting songs, i.e. favourite songs would have had the highest valence and energy levels, and sad songs would have the lowest energy and valence levels. From the individual song selection, it appeared impossible to select songs that solely varied in mood valence and having equal energy levels. This implies that valence and energy ratings are not fully independent of each other in inducing mood with music. This result is in line with findings of psychobiological theory of aesthetics (Berlyne 1971). This theory proposes that a U-shaped relationship exists between arousal and liking, i.e. an average arousal level has the optimal liking level, and increasing and decreasing arousal levels would decrease liking levels (Berlyne 1971, Hargreaves and North 2008).

To cope with the large individual differences in music liking, individually selected song stimuli were chosen in the current study (Juslin and Sloboda 2010). This method assured that the songs stimuli selected indeed induced the targeted moods. However, this method also resulted in stimuli that were not controlled for other music characteristics such as familiarity, or characteristics inherent to the music as tempo or mode, which could impact mood (Juslin and Sloboda 2010, van der Zwaag *et al.* 2011). Future research should point out how the lessons learned from this study can be generalised to the impact of music listening to different types of music during a wide variety of driving scenarios.

4.4. Conclusion

In the current study, the influence of listening to music on mood, body state, and driving performance during

high and low demand drives were investigated. Moods were successfully induced with music, and driving without music was perceived with equal negative feelings as driving with negative valence music. Listening to negative music compared to no music while driving leads to decreased RRs and listening to positive music compared to no music leads to slower driving speed. Furthermore, increased driving demand led to an increased amount of swerving. In the present study music did not impair driving performance as often found in the literature. In contrast, listening to music can even lead to an improved mood and a more relaxed body state which could be beneficial for health in the long run.

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