



Background music as a risk factor for distraction among young-novice drivers

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ABSTRACT

There are countless beliefs about the *power of music* during driving. The last thing one would think about is: how safe is it to listen or sing to music? Unfortunately, collisions linked to music devices have been known for some time; adjusting the radio controls, swapping tape-cassettes and compact-discs, or searching through MP3 files, are all forms of distraction that can result in a near-crash or crash. While the decrement of vehicular performance can also occur from capacity interference to central attention, whether or not music listening is a contributing factor to distraction is relatively unknown. The current study explored the effects of driver-preferred music on driver behavior. 85 young-novice drivers completed six trips in an instrumented Learners Vehicle. The study found that all participants committed at-least 3 driver deficiencies; 27 needed a verbal warning/command and 17 required a steering or braking intervention to prevent an accident. While there were elevated positive moods and enjoyment for trips with driver-preferred music, this background also produced the most frequent severe driver miscalculations and inaccuracies, violations, and aggressive driving. However, trips with music structurally designed to generate moderate levels of perceptual complexity, improved driver behavior and increased driver safety. The study is the first within-subjects on-road high-dose double-exposure clinical-trial investigation of musical stimuli on driver behavior.

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1. Introduction

In-car listening may seem trivial, but the extent to which it has become a fundamental component of the driving experience among 72–100% of drivers is evident (Arbitron/Edison, 1999; Dibben and Williamson, 2007; Quicken Insurance, 2000; Stutts et al., 2003, 2005; Young and Lenne, 2010). From the millennium onwards, the most popular location reported for music listening is the automobile (Rentfrow and Gosling, 2003; Sheridan, 2000; Sloboda, 1999; Sloboda et al., 2000; Sloboda et al., 2001). Nevertheless, to date there is no clear evidence that answers the following two questions: does listening to music affect driving performance and vehicular control? If it does, then are all music styles similar, or are there differential effects based on structural features within the music itself? These were among the overriding questions that serve as impetus of the current study.

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Oblad (2000) studied the relationship between music, driver, and the automobile. She presumed that individuals have specific expectations when they play music in the car; it is not necessarily the music that drivers want to listen to, but rather they wish to spend time in the car with music in the background. As there seem to be countless beliefs about the *power of music* in all aspects of human activity, drivers feel that music will undoubtedly enhance vehicular control; music selections can match the mood of the journey (Sheller, 2004), or relax drivers (Dibben and Williamson, 2007). Moreover, research has listed music as an effective method for maintaining alertness to counter monotony and sleepiness while driving (Cummings et al., 2001; Oron-Gilad et al., 2008; Reyner and Horne, 1998). To this end, CD compilations for driving have become popular, and even endorsed by insurance companies (Direct Line Car Insurance, 2013). Auto enthusiasts recommend tracks via the web, motor-magazines (Autotrader, 2010), and auto clubs (BBC News, 2004; Betts, 2009; RAC, 2004; USA Today, 2004). Recently, *car-a-oke* has become fashionable, with roughly 70% drivers treating their car as a personal 'karaoke booth'. Accordingly, many admit to embarrassing musical tastes that they indulge only in the car; male motorists swap stereotypical masculine driving tracks for 'chick-hits', and female drivers belt-out macho metal-rock classics (Barari, 2010; SEAT, 2010).

Cars elicit a range of feelings from the 'pleasure of driving' to the 'thrill of speed' (Sheller, 2004), and drivers envisage 'feeling

secure' and 'protected'. Oblad (2000) reported that when drivers liked the track, they felt 'inside' the music, and perceived the driving experience as 'impenetrable'. Therefore, the last thing one would think about is: how safe is it to listen or sing to music while driving an automobile? Yet, fine-tuning radio controls, swapping cassette-tapes, inserting CDs, and scrolling through playlists, have all been linked to eyes directed inward away from the road with one hand on the steering wheel (Horberry et al., 2006; Lee et al., 2012; Wikman et al., 1998). During the five seconds needed to change a CD, the car will have traveled 156 meters (500 feet) with the driver essentially unaware of the road environment (RAC, 2009). Moreover, among 91% of drivers, such behaviors occur several times per trip, with as many as seven transactions per hour (Stutts et al., 2003, 2005; Young and Lenne, 2010). Shifting attention to audio controls denotes neglecting primary tasks such as lane-keeping or looking for other vehicles, and involvement with music devices has been found to generate similar effects of driver distraction as do mobile phones (Brumby et al., 2007; Salvucci et al., 2007; Young and Lenne, 2010).

While the frequency of music-related automobile accidents is not known, anecdotes with photos are available (Car-Accidents.com, 2013). Unfortunately, collisions linking *structural interference* with music devices have been known for some time (McEvoy et al., 2006; RAC, 2009; Stevens and Minton, 2001; Stutts, 2001; Stutts et al., 2001a, b). Two recent meta-analyses (Young and Lenne, 2010; Young and Salmon, 2012) found that adjusting the radio controls, swapping tape-cassettes and compact-discs, or searching through MP3 files, are all forms of distraction that can result in a near-crash or crash with odds estimated at 0.6–2.3%. However, the decrement of vehicular performance can also occur from *capacity interference* to central attention (Consiglio et al., 2006). Yet, in reference to the *music* itself, little information is available. First, traffic researchers and accident investigators are not mindful of risks associated with music. One reason for this gap is that some (high profile) studies have totally 'side-blinded' readers by disregarding music as a risk factor (Dingus et al., 2006; Klauer et al., 2006a, b), while other studies have wrongly declared that music is 'not at all associated with negative driving performance' (Stutts et al., 2003, p. 205). Second, there are widely spread popular beliefs about music listening and/or singing as being the most valid activity a driver can engage in while on the road, causing *little-to-no-risk* compared to all other activities that might lead to distraction (Patel et al., 2008; Titchener et al., 2009; Unal et al., 2012; White et al., 2004; Young and Lenne, 2010). It would seem, then, that both traffic researchers and drivers underestimate in-car distraction from activities, which are widely acceptable but not necessarily safe, involving a range of mundane activities such as *simply listening to music* (Patel et al., 2008; White et al., 2004; RoSPA, 2007; RSC, 2006).

Most drivers aged between 16 and 30 choose to travel with Pop, Rock, Dance, Hip-Hop, House, and Rap styles (ACF, 2009; Brodsky, 2002; Brodsky and Kizner, 2012; Daily Telegraph, 2009; Dibben and Williamson, 2007; Milne, 2009; Quicken Insurance, 2000). These highly energetic aggressive fast-paced musics are played at strong intensity levels. Whether or not music listening is a contributing factor to distraction is relatively unknown (Eby and Kostyniuk, 2003; RSC, 2006; Smith, 2006). Yet, any competing stimulus or activity that interferes with processes that have detrimental effects on driver awareness, road position, speed maintenance, control, reaction times, or negotiation of gaps in traffic – should be treated as a risk factor for distraction (NHTSA, 2000; Shinar, 2007; Young and Lenne, 2010; Young and Salmon 2012). As safe and effective driving necessitates the detection of auditory information embedded in a background of continuously changing sounds (Slawinski and MacNeil, 2002), the presence of music in vehicles along with road noise must be considered. For example, listening to music

may mask the sounds of external warning signals (sirens/horns), vehicle-design critical warning signals (beeps/buzzes), and self-monitoring sounds (engine-revs) (Bellinger et al., 2009; Dibben and Williamson, 2007; Ho and Spence, 2005, 2008; RoSPA, 2007).

What is in the music that makes *in-car listening* a risk factor? Certainly, a range of variables shape responses, including: age, arousal, familiarity, gender, personality, musical preferences, and mood (North and Hargreaves, 1995, 1999). Nevertheless, all drivers who listen to songs process sounds as well as words, and often sing aloud or tap along to the rhythm (Dibben and Williamson, 2007; Pecher et al., 2009; van der Zwaag et al., 2012). Unfortunately, drivers are not aware that as they get 'drawn-in' by a song, they move from an *extra-personal space* involving driving tasks, to a more *personal space* of active music listening (Driving Risk Management, 2011; Fagiolo and Ferlazzo, 2006; Ferlazzo et al., 2008; Power, 2009). Further, there is an issue of *complexity*; the greater the structural complexity of the music, the larger the effects on the critical tasks necessary to safely operate a motor vehicle. For example, momentary peaks in loud music can disrupt vestibulo-ocular control, decreasing the window for responses to unexpected red rear break lights, and increase reaction times for peripheral signals during high-demand driving (Ayres and Hughes, 1986; Beh and Hirst, 1999; Consiglio et al., 2006; Horberry et al., 2006; McEvoy et al., 2006). Further, the pace of background music can alter perception of passing landscapes (Iwamiya, 1997); and rapid music can increase acceleration, cruising speed, and traffic violations (Brodsky, 2002; Konz and McDougal, 1968). Finally, young drivers demonstrate significantly more at-risk driving behaviors with up-tempo music (Gregersen and Berg, 1994).

Concerns about *in-car listening* have attracted few explorations. Unal et al. (2012) explored music as stimuli that mediate mental effort and cognitive load for monotonous and complex traffic environments. Further, two studies (Pecher et al., 2009; van der Zwaag et al., 2012) hypothesized interactions between processing styles and characteristic driving behavior mediated by 'sad' vs. 'positive' musics (i.e., mood valance and energy levels). But, for various methodological reasons, all of these offer little insight except to conclude that future studies must provide more rigorous control over music listening conditions, and that samples of novice drivers might provide a completely different outcome. In this light, the current study is designed to explore the effects of driver-preferred music among young-novice drivers, in a real-world on-the-road environment, employing instrumented Learners Vehicles.

As a group, young-novice drivers are more involved in crashes beyond any other age group (Braitman et al., 2008; Levey, 2010; McKnight and McKnight, 2003; Peek-Asa et al., 2010; Shinar, 2004; Tal, 2011; Williams, 2003). On a per-mile basis, non-fatal accident rates for these drivers are four times higher than drivers aged 18–20, and ten times more than drivers over 20. Within their first year, crash-rates are about one-in-five, more often involving male drivers. Elevated crash-rates for young-novice drivers are attributable to both driving inexperience, as well as a predisposition for impulsivity and risk-taking as a characteristic lifestyle (Gregersen and Berg, 1994). Even within a Graduated Driving Licensing system, initial low frequencies observed during accompanied-driving periods are replaced by steep increases in risk propensity and violations upon transition to unsupervised solo-driving (Prato et al., 2010). Although significant declines in accident-rate after the first 800 km (500 miles) are apparent, young-novice drivers remain more prone to distraction as they are less efficient in processing visual information needed to drive safely while engaging in other non-driving tasks – such as music listening. Finally, two prevalent factors that increase crash-risk among young novice drivers are late-night driving, and teenage passengers (Williams, 2003). Accordingly, not only have newly licensed drivers had less practice at night, but also fatigue and alcohol

consumption is all the more prevalent in the late hours. Further, as the vehicle serves as a place for social functioning where friends can be together independently of their parents, the presence of three or more peer passengers – along with loud music – is a distraction that can increase the crash-risk four-fold (Arnett, 2002). Hence, legislation concerning young-novice drivers has limited drive time, restricted the number of passengers, regulated alcohol consumption, and banned cellular phone use. But yet, involvement of young-novice drivers in road crashes and fatal accidents is still a main concern, and therefore widening the research inquiry is paramount.

The overriding goal of current study is foremost to explore driver-preferred music background as a risk factor for distraction among young-novice drivers. In this context distraction is measured by *driver deficiency* (that is, the frequency and severity of deficient driving behavior including miscalculation, inaccuracy, aggressiveness, and violations) as well as by decreased *vehicle performance* (that is, the frequency and severity of prototypical mechanical events). These are measured by both standardized assessments from expert observers accompanying the drivers, as well as by data recorded from in-vehicle hardware installed directly to the controller area network and on-board diagnostics of the vehicle. We hypothesized that young-novice drivers would demonstrate significantly increased deficient driving behaviors and mechanical events while driving with their preferred music accompaniment brought from their home than for trips without music. That is, in-cabin vehicular listening will be seen as increasing risks for distraction leading to traffic accidents among young-novice drivers. A second goal of the study was to assess an alternative music background designed specifically for increased driver safety (Brodsky and Kizner 2012). In this context the study explores a different genre of music, with a more controlled structure and employment of musical features. We hypothesized that young-novice drivers would demonstrate significantly decreased deficient driving behaviors and mechanical events while driving with an alternative music accompaniment than when driving with their own preferred music accompaniment. That is, the alternative music background will be seen as decreasing risks for distraction leading to traffic accidents, and increasing driver safety, among young-novice drivers. Finally, the study seeks to examine the role of individual differences (such as gender and impulsivity/sensation-seeking) as personal covariates that might mediate music effects on driving behavior.

2. Methods

2.1. Participants

2.1.1. Young-novice drivers

The participants were 85 young-novice drivers, 17.6 years old ($SD=0.41$), with a valid Driver's License for seven months ($SD=2.64$); each received a \$50 gift voucher. There were slightly more male drivers (58%), but this gender difference is not statistically significant ($\chi^2_{(1)}=1.52$, $p=0.22$). We point out that the gender distribution of 17-year-old drivers in Israel is 63% male (Israel Central Bureau of Statistics, 2007). The residential area that was used to recruit the participants was roughly 650 square-kilometers (254 square-miles). The participants were from various ethnic backgrounds of lower-to-upper middleclass socioeconomic levels. Before the study each participant read an Information Letter, and returned a Consent To Participate form signed by a parent. By self-report, none of the participants had been prosecuted by a traffic court, and 92% stated that they had never been in a collision. 86% of the participants reported they listen to music *all the time* while driving, 99% drive with music they describe

as *moderately-fast/very-fast* paced, and 94% claim to play music at *moderately-loud/loud* volumes. Each participant completed the 'Impulsivity and Sensation-Seeking Scale' (*ImpSS*; Zuckerman et al., 1993); there was a medium level of *ImpSS* ($M=8.32$, $SD=2.65$; low-*Imp* $M=2.63$, $SD=1.39$; mid-*SS* $M=5.7$, $SD=1.82$).

2.1.2. Accompanying driving instructors

Two driving instructors served as on-site clinical research monitors and expert observers; both were male, roughly 62 years old ($SD=2.83$), with 39 years experience as a licensed driving instructor. Each brought a Learners Vehicle to the field study. Though blind to the specific research objectives, they understood that the investigation explored the effects of music among young-novice drivers.

2.2. Materials and measures

2.2.1. Research protocol and monitor and post-trip diary

The accompanying driving instructors employed a 1-page format marked by a unique ID number (PIN) per participant. This empirical protocol indicated the pre-assigned rotation order of all three driving conditions. On the sheet, trip details prior-to and after each trip (i.e., date, time, kilometer, music volume) were registered, and there was a text-box for comments regarding driver behavior, and the necessity to intervene (verbal warnings, commands, or physical steering/braking maneuvers). Then, after each trip, a diary-like post-trip questionnaire was filled-in by each participant who rated their ability to execute driver caution, and their perceived level of enjoyment from the music background.

2.2.2. Impulsivity and sensation-seeking scale

ImpSS was employed as an independent variable for descriptive and explanatory purposes. Originally this scale was an independent factor of the Zuckerman-Kuhlman Personality Questionnaire, which was then re-configured as a 19-item 'true/false' response scale (Zuckerman et al., 1993). Unlike other sensation-seeking scales, *ImpSS* items do not specify behaviors or activities such as drinking, drug use, sex, and sports, as these may be more or less sanctioned in some cultures. *ImpSS* has high internal consistency ($\alpha=0.77-0.82$). Items are tallied (1 = True, 0 = False) to provide a total scale score (range 1–19). For the sake of comparative analyses, participants with scores from the bottom-20% and top-20% were grouped separately; differences between low-*ImpSS* ($n=18$, $M=4.66$, $SD=1.28$, range 1–6) vs. high-*ImpSS* ($n=18$, $M=11.94$, $SD=1.06$, range 11–19) were statistically significant ($F_{(1,34)}=345.25$, $MSe=1.38$, $p<0.0001$, $\eta_p^2=0.91$).

2.2.3. Profile of mood states

POMS was employed as a dependent variable to monitor driver mood per trip, as well as across driving conditions. McNair et al. (1971) developed this 65-item adjective list as seven 8-item affect subscales (anger, confusion, depression, fatigue, friendliness, tension, and vigor). Nevertheless, several 32-item brief versions have been reported as highly reliable ($\alpha=0.76-0.95$; test-retest $r=0.65-0.75$). The current study employed a 32-item version based on four subscales in an effort to assess both positive affect (*PA*, Friendly + Vigor) and negative affect (*NA*, Tension + Fatigue). A general mood score (*GMS*) was calculated by deducting *NA* from *PA*.

2.2.4. Young-novice driver deficiency rating scale

YnDDrs was adapted from McKnight and McKnight (2003) who identified 11 broad categories accounting for 40 highly potential behavioral contributors of accidents among young-novice drivers. *YnDDrs* was employed as a rating scale for observed deficient driving behavior per each trip. However, an additional twelfth category was added in an effort to account for intervention maneuvers

Table 1
Traffilog event list and weighted scoring.

Event category	Event behavior	Score
Speeding	Speed violation above 100 Kph	15
	Speed violation above 130 Kph	25
Acceleration	Acceleration violation level 1	10
	Acceleration violation level 2	20
	Acceleration violation level 3	33
Braking	Brake level 1	10
	Brake level 2	20
	Brake level 3	30
	Brake level 4	40
	Brake level 5	70
	Brake level 6	80
	Brake level 7	90
Turning	Left turn level 1	10
	Left turn level 2	20
	Left turn level 3	30
	Left turn level 4	60
	Left turn level 5	70
	Right turn level 1	10
	Right turn level 2	20
	Right turn level 3	30
	Right turn level 4	60
	Right turn level 5	70
RPMs	Rpm above 2300 in acceleration 20 kph	15
	Rpm above 2600 in acceleration 40 kph	15
	Rpm above 3000 in acceleration 60 kph	15
	Rpm above 3300 in acceleration 80 kph	15
	Rpm above 3400 in acceleration 100 kh	15

(that could have been executed to avoid an accident). *YnDDrs* provides a calculated total score emulating a 'trip-risk profile'. All 40 behaviors are rated on 4-point scale (1 = Least Severe, 4 = Most Severe), while verbal warnings/commands are marked as 5-points, and physical interventions are marked as 6-points. Weighting was employed to transform event-frequency to event-severity; a square-number sequence ($x_n = n^2$) converted raw responses 1, 2, 3, 4, 5, 6 to weighted values 1, 3, 9, 16, 25, 36. Higher *YnDDrs* scores indicate more deficient at-risk driving. Reliability analyses of McKnight and McKnight's original 11-category scale (*Chronbach's* $\alpha_{11} = 0.70$), and the enhanced 12-category (*Chronbach's* $\alpha_{12} = 0.71$) assessments demonstrated that the measure was consistent and dependable.

2.2.5. NewDriver-DNA

Proprietary software developed by Traffilog (*Traffilog.com*) was used to process a range of mechanical and behavioral data, as well as a set of predetermined interaction variables that are generated and calculated by the IVDR. Twenty-seven event-behaviors from five independent event-categories are systematically logged, and data interpretation capabilities combine driver behaviors, driving skills, and vehicular performance – in real time. See Table 1. Both frequency and severity of events are calculated per condition. Based on thresholds of event-severity scores, on-road driving performances are coded into one of three overriding driver profiles (≤ 49 = cautious; $50-249$ = moderate; ≥ 250 = aggressive) referred to as *NewDriver-DNA*.

2.3. Equipment

2.3.1. In-vehicle data recorder

The *Vehicular Unit* (Traffilog) maintains a direct connection with the controller area network (CANBUS) and on-board diagnostics (OBD); it reads the vehicle protocol, and measures applied G-force (G-sensor and ECM systems) during driving. Quantifying acceleration and GPS data, the web-based software calculates G-sensor triggered events; these are subsequently scored, and then codified into driving profiles (cautious, moderate, or aggressive driving). The *VU* is comprised of a single end-unit and numerical keypad;

the decoder-connection employs pattern recognition algorithms to reduce the on-line stream (at a sampling rate of 100 ms) into meaningful maneuvers, transmitted through a wireless network (with on-air updates every 10 s) to a secure application server in real time. Data is synchronized with both vehicle-specific and driver-specific records.

2.3.2. Digital sound level meter

Sound recordings were taken from each Learners Vehicle to convert numerical data (as logged from LED displays of the CD players) to sound pressures. Intensity levels were recorded with a *Radio Shack* digital sound level meter (Model 33-2055) using a C-weighting curve at a sampling rate of 0.2 s continuously over an interval of 5 s for integrated average *Spls* (marking both Min–Max ranges).

2.4. Music stimuli

Driving conditions were variegated by aural background. There were two trips with driver-preferred music (*DrvPrefMus*), two trips with in-car music alternative background (*InCarMus*), and two trips with no music (*NMus*) as a control condition. Trips with music consisted of a high-dose 40-minute exposure; this level of saturation is 10-times more potent than as employed by van der Zwaag et al. (2012) who reported effects within 4-minutes.

2.4.1. Driver-preferred music

The participants created playlists from their home collections. Unal et al. (2012) claims that this strategy increases *ecological validity* as selections are based on familiarity of tracks as usually heard while driving. On average, 12-tracks per driver was brought to the study; there were 1035 music pieces in total. The majority (67%) of the pieces were international tracks, while the remaining selections (33%) were local Hebrew songs. A further musicological analysis indicates that six overriding music genres account for more than 90% of driver-preferred musics. See Fig. 1.

2.4.2. In-car music alternative background

Brodsky and Kizner (2012) designed music for improved driver safety; this original music program does not include vocal performances with lyrics, nor covers well-known popular tunes. The 8-track 34-minute program boasts of music elements that are well balanced, with modest rhythmic qualities and tempo, optimal tone timbres, and conservative instrumental ranges, arrangements, voice textures, and intensities. The music contains lush harmonies, and while there is no specific melody line to sing with, vague melodic fragments intermittently come to the surface. Brodsky (2002) found that these characteristics provide a level of perceptual complexity that does not divert mental resources while driving. A sampler of the 8-item program can be heard at <http://in.bgu.ac.il/humsos/art/Pages/Scientific-Publications-warren.aspx>.

2.5. Vehicles

The study employed two automatic-gear Learners Vehicles with double accelerator and braking pedals. Each automobile had a manufacturer-fitted built-in dashboard-mounted CD player, with 2 sets of stereo speakers (cabin front and rear). The automobiles were: 2011 Red Volkswagen *Polo 1200TSI-DSG7*; 2008 White Suzuki *SX4 Sedan* (1600cc). In each vehicle an identical IVDR was installed and calibrated.

3. Procedure

Prior to the onset, the study was approved by a university Human Subjects Research and Ethics Committee. Teen-aged

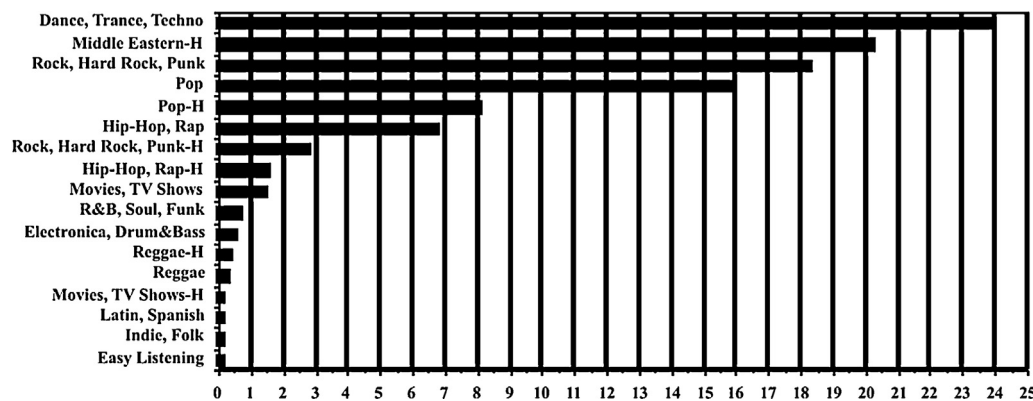


Fig. 1. Driver-preferred music brought from home by the participants: Y=music styles (genres), X=popularity (%). Note: H=Hebrew language.

recruiters contacted prospective participants by telephone, and then three pre-study documents were sent them via email. The driving instructors independently scheduled all sessions with the participants. At the first meeting, a valid driver license was inspected, a parental-signed consent form was collected, and a driver-preferred music playlist was collated. Participants came to their first session with CDs in hand (as for some it was required by empirical condition of the first trip); the CDs remained in the Learners Vehicles throughout all six trips. Each participant was allocated a pre-numbered (PIN) booklet for collecting behavioral data. Booklet (PIN) allocation was the method by which a pre-defined order of driving conditions was randomly assigned across the sample.

In the first session a short survey of descriptive data and the *ImpSS* scale was completed. Then, the accompanying driving instructor entered a 5-digit code on the IVDR keypad; the code comprised the participant's PIN (001–100), trip number (1–6), and empirical condition (1–3). Thereafter, all pre-trip details were registered. If the driving condition involved music, a CD was inserted in the car's disc-player. Participants regulated both track number and volume. All driving trips were structured in a similar fashion: from home participants drove via limited-access residential roads toward the closest divided boulevard leading to a hi-way (10 min); they continued along urban interstate freeway with 2- or 3-lane traffic in each direction separated by a median strip (30 min); finally, they returned home (10 min). Upon conclusion, the participants completed a post-trip survey including the *POMS* mood states. The accompanying driving instructor registered post-trip details, wrote a brief commentary describing the driver's behavior, and then completed the *YnDDRs* rating scale of deficient driving behavior. In the final sixth trip the participants also completed a Debriefing Survey, and signed a receipt for the \$50 gift voucher.

All six trips were completed within 2-weeks, in the same Learners Vehicle, with the same accompanying driving instructor. Subsequent analyses found no differences between the driving conditions for trip parameters (trip-time, trip-distance, or trip-speed), and no meaningful differences between the two driving instructors surfaced. IN TOTAL there were 510 trips, each lasting roughly 42 min (SD=3.38) for a total 357 h of on-road driving, covering a distance averaging 39.4 km (SD=6.99, 25 miles) per trip for a total 20,400 km (12,676 miles).

4. Results

The on-road investigation compared three aural-background driving conditions: driver-preferred music (*DrvPrefMus*), in-car music alternative (*InCarMus*), and no music (*NMus*). There were five dependent measures (both behavioral and mechanical). Scores from trips in the same conditions were collapsed, and entered into

separate within-subjects repeated-measures analyses of variance (ANOVAs). Then, delta (Δ) variables were formulated to highlight specific effects of the music condition by deducting data from the no-music condition (as a control-baseline). The results section first outlines behavioral data of the drivers (more general findings relating to the driving experience, driver mood states, and deficient driving behaviors), then the mechanical data from the in-vehicle data recorder are delineated, and finally integrated sound levels of the music as heard in the vehicle are presented.

4.1. Behavioral data

4.1.1. Participant-driver experience

Ecological validity of in-car listening: The participants reported a high-level of *concurrency* ($M=3.4$, $SD=0.58$) between the empirical trips and everyday driving. For the most part they reported that music brought from home was *highly-similar* ($M=3.82$, $SD=0.47$) to what they listen to when driving in their own vehicle. Nevertheless, a significant negative correlation surfaced for *concurrency* of music between impulsivity sensation-seeking traits and trips with their preferred music brought from home ($r=-.24$, $p<0.05$). That is, low-*ImpSS* drivers reported a higher correspondence of the music they brought to the study than high-*ImpSS* drivers ($M=3.61$, $SD=0.50$; $M=3.11$, $SD=0.58$; $F_{(1,34)}=7.61$, $MSe=0.30$, $p<0.01$, $\eta_p^2=0.18$). In addition, participant-adjusted *music volume* was perceived as *quite-similar* ($M=3.4$, $SD=0.58$) to the volumes they usually adjust in their own vehicles. Yet again, a significant negative correlation surfaced between *concurrency* of music volume and impulsivity sensation-seeking traits ($r=-.34$, $p<0.05$). That is, low-*ImpSS* drivers reported a higher correspondence between the volumes they adjusted than high-*ImpSS* drivers ($M=3.56$, $SD=0.51$; $M=2.89$, $SD=0.58$; $F_{(1,34)}=13.30$, $MSe=0.30$, $p<0.001$, $\eta_p^2=0.28$).

In-car music backgrounds: The participants reported a increased *awareness of the music* for trips with their preferred music brought from home than for trips with an alternative music background ($M=3.65$, $SD=0.44$; $M=2.89$, $SD=0.66$; $F_{(1,84)}=107.33$, $MSe=0.2280$, $p<0.0001$, $\eta_p^2=0.56$). Moreover, female drivers were more *aware* of the alternative music background than male drivers ($M=3.91$, $SD=0.19$; $M=3.76$, $SD=0.34$; $F_{(1,83)}=5.93$, $MSe=0.083$, $p<0.05$, $\eta_p^2=0.07$). In addition, participants reported increased *enjoyment of the music* for trips with their preferred music brought from home than for trips with an alternative music ($M=3.82$, $SD=0.30$; $M=2.21$, $SD=0.85$; $F_{(1,84)}=300.68$, $MSe=0.3672$, $p<0.0001$, $\eta_p^2=0.78$). Nevertheless, significant negative correlations were found between *enjoyment of the music* and impulsivity sensation-seeking traits for trips with an alternative music background ($r=-.37$, $p<0.05$). That is, low-*ImpSS* drivers reported to enjoy the alternative music more than

high-*ImpSS* drivers ($M=2.42$, $SD=0.88$; $M=1.81$, $SD=0.67$; $F_{(1,34)}=5.52$, $MSe=0.61$, $p<0.05$, $\eta_p^2=0.14$).

Perceived driver caution: The participants perceived a high level of driver caution ($M=3.76$, $SD=0.003$) in all three conditions. That is, there were no significant differences driving with or without music, or between the two music backgrounds. Yet, female drivers reported significantly higher levels of driver caution than male drivers on trips without music ($M=3.90$, $SD=0.29$; $M=3.66$, $SD=0.50$; $F_{(1,83)}=6.97$, $MSe=0.170$, $p<0.01$, $\eta_p^2=0.0775$), and in trips with preferred music brought from home ($M=3.87$, $SD=0.25$; $M=3.67$, $SD=0.42$; $F_{(1,83)}=6.17$, $MSe=0.129$, $p<0.05$, $\eta_p^2=0.0692$). Nevertheless, a significant negative correlation surfaced between perceived driver caution and impulsivity sensation-seeking traits for trips with an alternative music background ($r=-.41$, $p<0.05$). That is, low-*ImpSS* drivers perceived a greater level of driver caution than high-*ImpSS* drivers ($M=3.91$, $SD=0.19$; $M=3.64$, $SD=0.41$; $F_{(1,34)}=6.69$, $MSe=0.104$, $p<0.05$, $\eta_p^2=0.17$).

4.1.2. Participant mood states (POMS)

The participants indicated significantly more positive affect than negative affect in all three driving conditions. See Table 2a. When entering PA and NA into separate ANOVAs, there were significant effects across conditions: PA ($F_{(2,168)}=50.213$, $MSe=0.1176$, $p<0.0001$, $\eta_p^2=0.38$); NA ($F_{(2,168)}=21.128$, $MSe=0.0739$, $p<0.0001$, $\eta_p^2=0.20$). Contrast statistics revealed significantly more positive mood than negative mood, as well as significantly less negative mood, for trips with preferred music brought from home than for trips without music or those with an alternative music background. In addition, there was a significant effect of General Mood State ($F_{(2,168)}=43.961$, $MSe=0.3064$, $p<0.0001$, $\eta_p^2=0.34$). As can be seen in Table 2a, GMS was elevated for trips with preferred music. Although there were no 2-way interaction effects, significant positive correlations surfaced between NA and impulsivity sensation-seeking traits for trips with an alternative music background ($r=0.24$, $p<0.05$). That is, high-*ImpSS* drivers were significantly more negative in affect than low-*ImpSS* drivers for trips with an alternative music background ($M=1.94$, $SD=0.42$; $M=1.57$, $SD=0.37$; $F_{(1,34)}=8.01$, $MSe=0.16$, $p<0.01$, $\eta_p^2=0.19$). It should be pointed out that high-*ImpSS* drivers were also significantly more negative in affect than low-*ImpSS* drivers for trips without music ($M=1.80$, $SD=0.35$; $M=1.47$, $SD=0.28$; $F_{(1,34)}=9.21$, $MSe=0.10$, $p<0.01$, $\eta_p^2=0.21$).

Effect of music: Finally, in an effort to highlight the benefit/detriment of music on mood states during driving, delta (Δ) variables were created. As can be seen in Table 2b, the differential effects of music on mood were statistically significantly for trips with preferred music brought from home but not for trips with an alternative music background. ANOVAs found statistically significant effects: PA- Δ ($F_{(1,84)}=92.217$, $MSe=0.0805$, $p<0.0001$, $\eta_p^2=0.52$); NA- Δ ($F_{(1,84)}=48.188$, $MSe=0.0499$, $p<0.0001$, $\eta_p^2=0.36$); GMS- Δ ($F_{(1,84)}=96.954$, $MSe=0.188$, $p<0.0001$, $\eta_p^2=0.54$). Contrast statistics revealed that the effects of music on mood states were significantly elevated (in both expected directions – \uparrow PA and \downarrow NA) for trips with preferred music.

4.1.3. Driver deficiencies (YnDDrs)

Frequency of Deficient Driving Behavior: Driver behaviors as observed by the accompanying driving instructors were rated. Out of a total 510 trips, only 61 trips (12%) were totally efficient without violations. These well-organized and competent trips were carried-out by 24 participants (i.e., 28% of the sample). The findings show that all 85 participants committed an average three driver deficiencies in at least 1-out-of-6 trips. When comparing between the conditions, 77 drivers (90%) committed at least one violation in

trips with an alternative music background, 78 drivers (92%) committed at least one violation in trips without music, and 84 drivers (98%) committed at least one violation in trips with preferred music brought from home; differences between the conditions were statistically significant (Cochran $Q_{(2)}=7.17$, $p<0.05$). The driving condition with the least number of participants involved in violations, as well as the lowest number of deficiencies per driver, was driving with an alternative music background; in this condition there were significantly less violations relating to lane keeping and lane use, attention sharing, searching ahead for distance between cars, searching before turns, and adjusting speed.¹ In addition, a great number of participants committed the same violations on both trips in the same condition. In general, the most frequent driver deficiencies were: overzealous speed for traffic or road conditions (20%), difficulty in maintaining attention (14%), following and keeping distance from the car ahead (11%), inappropriate lane use (11%), driving with one hand on the wheel (10%), lane weaving (5%), and overtaking vehicles (2%). Taken together, these account for 73% of deficient driving behaviors among the sample. Finally, it is worrisome that 32% of the sample generated at least one violation that required a verbal warning or strict emergent command, while 20% committed a violation that necessitated an actual physical intervention (i.e., steering or a braking maneuver) in order to avoid an imminent crash.

Severity of deficient driver behavior: Beyond the frequency, it is paramount to scrutinize the severity of driver deficiencies as it may only take one severe event to cause a fatal accident. Weighted ratings of event-severity were tallied for each subcategory. See Table 3a. As can be seen in the Table, general effects of the music were found for 6-out-of-11 categories, and these indicate an overall trend for increased levels of severity in trips with driver-preferred music brought from home. When entering event-severity scores in an ANOVA, statistically significant effects surfaced ($F_{(2,168)}=8.2579$, $MSe=509.54$, $p<0.001$, $\eta_p^2=0.09$); contrast statistics revealed that trips were significantly more efficient (i.e., safer) when driving with an alternative music background than either trips with driver-preferred music or trips without music. See Table 3b. Although no 2-way interactions surfaced, higher event-severity scores were seen more for high-*ImpSS* drivers low-*ImpSS* drivers in every driving condition: *NMus* ($M=66$, $SD=37.4$; $M=52$, $SD=37.3$); *DrvPrefMus* ($M=70$, $SD=33.6$; $M=59$, $SD=22.4$); *InCarMus* ($M=51$, $SD=20.6$; $M=35$, $SD=29.1$). These differences were most outstanding for trips with an alternative music background, whereby a positive significant correlation surfaced between impulsivity sensation-seeking and event-severity scores ($r=.22$, $p<0.05$). Finally, male drivers demonstrated an overall higher frequency of severely deficient driving behavior than female drivers, but these did not achieve levels of statistical significance.

Control check: To rule out the possibility that the above findings may have been biased by penalizing 25 points against each intervention consisting of a verbal warning/command (committed by 32% of the sample), or by penalizing 36 points against each intervention consisting of a physical manipulation (committed by 20% of the sample), a data subset exclusively reflecting McKnight and McKnight's original 11-category model was analyzed. These results indicated statistically significant main effects (*NMus*: $M=38$, $SD=26.5$; *DrvPrefMus*: $M=43$, $SD=23.6$; *InCarMus*: $M=32$, $SD=19.2$; $F_{(2,168)}=12.06$, $MSe=207.29$, $p<0.0001$, $\eta_p^2=0.13$); contrast statistics confirmed the validity of all our previous findings reported above.

¹ Because of space constraints these data are not fully presented. More details are available from the first author upon request.

Table 2
POMS 32-item brief research version.

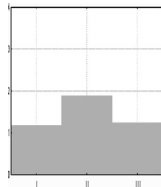
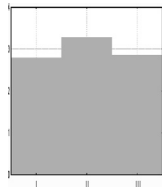
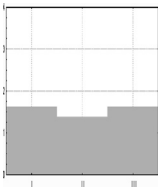
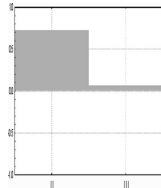
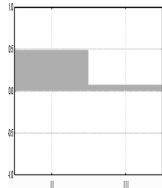
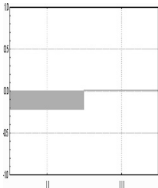
	General Mood State M (SD)	Positive Affect M (SD)	Negative Affect M (SD)	Positive vs Negative Affect		
				t	df	p
(a) Driving condition						
I NMus	1.17 (0.89)	2.78 (0.59)	1.62 (0.39)	12.22	84	<0.0001
II DrvPrefMus	1.89 (0.59)	3.27 (0.44)	1.38 (0.20)	29.49	84	<0.0001
III InCarMus	1.24 (0.77)	2.85 (0.52)	1.62 (0.39)	14.71	84	<0.0001
						
(b) Effect of music						
II DrvPrefMus	0.72 (0.88)	0.49 (0.55)	-0.23 (0.41)	7.51	84	<0.0001
III InCarMus	0.06 (0.83)	0.07 (0.49)	0.01 (0.42)	0.71	84	0.482
						

Table 3
Young-novice driver deficiency rating scale (*YnDDrs*): severity of observed deviations.

	I	II	III	<i>p</i>
	NMus	DrvPrefMus	InCarMus	
	<i>M</i> (SD)	<i>M</i> (SD)	<i>M</i> (SD)	
(a) <i>Categories</i>				
1. Vehicle control	2.99 (4.62)	4.60 (5.58)	3.44 (4.71)	*
2. Traffic controls use	7.91 (7.08)	7.23 (6.02)	5.82 (5.95)	*
3. Attention	5.15 (4.54)	6.66 (5.14)	3.94 (4.17)	***
4. Driver fatigue	0.44 (1.60)	0.16 (0.84)	0.65 (2.03)	
5. Search ahead	4.20 (5.75)	5.69 (5.81)	3.62 (4.62)	*
6. Search to the side	0.50 (0.49)	0.09 (0.87)	0.19 (1.22)	
7. Search to the rear	1.03 (2.75)	0.93 (2.83)	0.65 (2.08)	
8. Adjusting speed	7.91 (5.67)	8.82 (5.44)	6.96 (5.50)	**
9. Maintaining space	2.34 (5.05)	2.05 (4.06)	1.74 (3.11)	
10. Signals	1.01 (3.23)	0.92 (2.56)	0.48 (1.82)	
11. Emergencies	4.89 (6.96)	5.76 (7.00)	4.65 (6.50)	**
12. Interventions	12.76 (15.3)	10.92 (13.6)	8.29 (12.7)	(0.06)
(b) <i>Total score</i>				
<i>YnDDrs</i> total	50.68 (37.3)	53.89 (31.4)	40.42 (25.8)	***
(c) <i>Effect of music</i>				
<i>YnDDrs</i> −Δ	3.21 (34.3)		−49.13 (37.2)	***

* = $p < .05$.

** = $p < .01$.

*** = $p < .001$.

Effect of music: Finally, in an effort to highlight the benefit/detriment of music on driver deficient behavior, delta (Δ) variables were created. As can be seen in Table 3c, the differential effects of music on deficient driving behaviors were statistically significant ($F_{(1,84)} = 238.30$, $MSe = 488.63$, $p < 0.0001$, $\eta_p^2 = 0.74$). Contrast statistics revealed that music increased event-severity for trips with driver-preferred music brought from home beyond levels demonstrated in trips without music. Yet, quite to the contrary, music decreased event-severity for trips with an alternative music background beyond levels demonstrated in trips without music, indicating increased levels of driver safety. No 2-way interaction effects surfaced.

4.2. Mechanical data

From 27 event-behaviors in six event-categories that were logged from the in-vehicle data recorders, two global scores were calculated: event-frequency and event-severity per condition. See Table 4a. As can be seen in the Table, both frequency and severity of events were higher in trips with driver-preferred music brought from home. When entering these scores in two separate ANOVAs, statistically significant effects surfaced: Frequency ($F_{(2,168)} = 5.1108$, $MSe = 18.498$, $p < 0.01$, $\eta_p^2 = 0.06$); Severity ($F_{(2,168)} = 5.2009$, $MSe = 5252.80$, $p < 0.01$, $\eta_p^2 = 0.06$). Contrast statistics revealed that in trips with driver-preferred music there were significantly more violations that were more severe in risk, than in either trips with an alternative music background or trips without music. Although no 2-way interactions surfaced, male drivers were involved in significantly more events at significantly greater severities in every condition than female drivers. See Table 5a. In addition, positive correlations surfaced between ImpSS traits and both event-frequency and event-severity for all conditions: NoMus ($r = .35$, $p < 0.05$; $r = .33$, $p < 0.05$), DrvPrefMus ($r = .24$, $p < 0.05$; $r = .22$, $p < 0.05$), In-carMus ($r = .35$, $p < 0.05$; $r = .37$, $p < 0.05$). The analysis indicated that high-ImpSS drivers were more involved in events with increased risk in every driving condition than low-ImpSS drivers, and these were statistically significant in trips without music and in trips with an alternative music background. See Table 5b.

Control check: To rule out the possibility that the above findings may have been biased by mechanical data triggered from 3D G-sensors, or algorithmically derived maneuvers, an exclusive set of mechanical events targeting RPMs taken directly from the CANBUS and OBD was analyzed. The results indicate statistically significant main effects (NMus: $M = 24$, $SD = 39.8$; DrvPrefMus: $M = 36$, $SD = 56.7$; InCarMus: $M = 25$, $SD = 44.6$; $F_{(2,168)} = 5.78$, $MSe = 604.83$, $p < 0.01$, $\eta_p^2 = 0.06$); contrast statistics confirmed the validity of all our previous findings reported above.

Effect of music: To highlight the benefit or detriment of music on driving events as logged by the in-vehicle data recorders, delta (Δ) variables were created. As can be seen in Table 4b, the differential effects of music in driving events was statistically significant: Frequency- Δ ($F_{(1,84)} = 7.1534$, $MSe = 20.141$, $p < 0.01$, $\eta_p^2 = 0.08$); Severity- Δ ($F_{(1,84)} = 7.4964$, $MSe = 5669.6$, $p < 0.01$, $\eta_p^2 = 0.08$).

Profiling drivers (NewDriver-DNA): Finally, employing event-severity scores as an index, driver-participants were ranked into one-of-three overriding risk-categories: *cautious*, *moderate*, or *aggressive* drivers. See Table 6a. As can be seen in the Table, roughly 16% of the participants were coded as *cautious*, 64% as *moderate*, and 20% as *aggressive* drivers. Although gender proportions among *cautious* drivers were found as expected in relation to the sample size for two driving conditions (NMus and DrvPrefMus), there were less male drivers than expected among the *moderate* drivers in two conditions (NMus and DrvPrefMus). But, it should be noted that *aggressive* drivers in every condition were predominately male (which is unexpected and a disproportional percentage

of involvement). Further, significant positive correlations surfaced between impulsivity sensation-seeking and risk-categories: low-ImpSS drivers were found more among *cautious* drivers ($r = .45$, $p < 0.05$), while high-ImpSS drivers were found more among *aggressive* drivers ($r = .45$, $p < 0.05$).

In a post hoc between-condition analyses targeting the proportional differences of *cautious* and *aggressive* drivers, there were no differences in trips without music versus trips with an alternative music background, but there were nearly significant differences for these compared to trips with driver-preferred music brought from home (NMus vs. DrvPrefMus: $z = 1.61$, $p = 0.054$; InCarMus vs. DrvPrefMus: $z = 1.39$, $p = 0.082$). See Table 6b. Then, a second post hoc within-condition analyses targeting the proportional differences of *cautious* and *aggressive* drivers found no differences in trips without music or in trips with an alternative music background, but rather statistically significant differences surfaced for trips with driver-preferred music ($\chi^2_{(1)} = 4.50$, $p < 0.05$). This later finding is clearly a result of cautious drivers becoming more deficient, thereafter reclassified as an *aggressive* driver.

4.3. Integrated sound levels

The average reproduction volume of music heard in the vehicles was 85 dBs (with maximal intensities measured between 95 and 100 dBs). These are just slightly lower than measurements made by Ramsey and Simmons (1993) who reported in-cabin driver-adjusted audio output as 83–130 dBs. Driver-preferred music brought from home was heard at roughly 87.5 dBs ($SD = 4.24$, range = 78–98) while the alternative music background was heard at roughly 82.5 dBs ($SD = 3.92$, range = 68–88); these differences are statistically significant ($t = 7.01$, $df = 63$, $p < 0.0001$). Although such differences may appear to be related to music types, there is the possibility that differences in reproduction are solely biased by vehicle; that is, while no differences were found for driver-preferred music, significant differences of music reproduction were found between the vehicles for the alternative music background (White car: $M = 85$ dBs, $SD = 1.54$; Red car: $M = 80$ dBs, $SD = 3.63$; $F_{(1,62)} = 68.25$, $MSe = 7.43$, $p < 0.0001$, $\eta_p^2 = 0.52$). No other differences of music reproduction volumes were found for descriptive variables (i.e., gender or ImpSS).

5. Discussion and conclusions

5.1. Main findings

The current investigation presents four overriding findings:

- Incidence of driver deficiencies:** All 85 young-novice driver participants were observed with an average of three deficient driving behaviors in at least 1-out-of-6 trips; 32% needed a sudden verbal warning or command for action, and 20% (or 1-in-5) required a steering or braking maneuver to prevent an imminent accident.
- Driver affect:** There were significantly elevated positive mood states and enjoyment in trips with driver-preferred music brought from home compared to trips without music or trips with an alternative music background.
- Effects of music on driving performances:** In trips with driver-preferred music there was significantly more severely deficient driving behaviors, including: miscalculation, inaccuracy, traffic violations, and driver aggressiveness.
- Differential effects across music genres:** Driving with an alternative music background accompaniment produced significantly less deficient driving behaviors such as violations and aggressiveness, than when driving with preferred music brought from home.

Table 4
Logged driving events of in-vehicle data recorder.

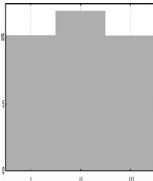
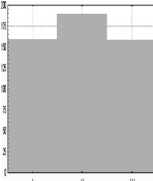
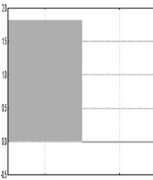
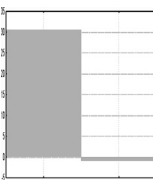
	I		II		III		
	NMus		DrvPrefMus		InCarMus		
	M	SD	M	SD	M	SD	
(a) Driving events							
Event-frequency	10.12	6.88	11.93	7.53	10.09	6.87	
Event-severity	158	120	189	132	157	111	
(b) Effect of music							
Event-frequency-Δ			1.81	6.04	-0.30	5.85	
Event-severity-Δ			30.5	102	-1.18	99	

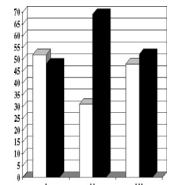
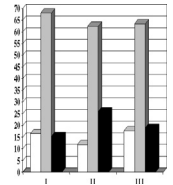
Table 5
Group differences of driving events measured by IVDR.

Condition	Male		Female		$F_{(1,83)}$	MSe	p	η_p^2
	M	SD	M	SD				
<i>(a) Differences of gender</i>								
I NMus								
Frequency	12	7.95	8	3.99	7.74	43.9	<0.01	0.09
Severity	190	140	113	62.2	9.41	13,220	<0.01	0.10
II DrivPrefMus								
Frequency	13	8.03	10	6.25	5.06	54.1	<0.05	0.06
Severity	216	141	150	107	5.53	16,497	<0.05	0.06
III InCarMus								
Frequency	12	7.49	8	4.90	9.38	43.0	<0.01	0.10
Severity	189	124	113	78.8	10.2	11,572	<0.01	0.11
	Low		High		$F_{(1,34)}$	MSe	p	η_p^2
	M	SD	M	SD				
<i>(b) Differences of impulsivity sensation-seeking traits</i>								
I NMus								
Frequency	7	3.72	13	8.83	7.19	45.9	<0.05	0.18
Severity	100	59.6	203	172	5.80	16,528	<0.05	0.15
II DrivPrefMus								
Frequency	9	6.79	14	6.92	3.83	47.0	<0.06	0.10
Severity	145	117	221	128	3.40	15,136	<0.07	0.09
III InCarMus								
Frequency	6	3.6	12	6.25	11.3	26.0	<0.01	0.25
Severity	83	50.1	186	98.0	15.7	6063	<0.01	0.32

Table 6

Traffilog risk profiles–NewDriver-DNA (Nd-DNA).

Driver profile	I		II		III	
	NMus		DrvPrefMus		InCarMus	
	N	%	N	%	N	%
(a)						
Cautious (white)	14	17	10	12	15	18
Moderate (gray)	58	68	53	62	54	63
Aggressive (black)	13	15	22	26	16	19
Total	85	100	85	100	85	100
(b)						
Cautious (white)	14	52	10	31	15	48
Aggressive (black)	13	48	22	69	16	52
Total	27	100	32	100	31	100



To summarize: 17–18 year-old young-novice drivers who lack the finely-honed skills and experience necessary to efficiently control a vehicle, prefer to drive with music that on the one hand boosts a more positive mood and their enjoyment, while on the other hand contributes to the risk for distraction and aggressiveness as seen by increases in deficient driving behavior, perceptual error, performance miscalculation, and traffic violations. In addition, music that is structurally designed to generate moderate levels of perceptual complexity, can be seen as mediating an improved vehicular performance leading to increased driver safety.

5.2. General findings

The current study implemented an *on-road* investigation with two instrumented Learners Vehicles and two accompanying driving instructors. This original and innovative platform for driving research offers a high level of empirical control, ecological validity, and reliability. Moreover, the platform also offers the utmost level of safety for young-novice drivers, who for all legal purposes may be certified, but have had less than 12-months experience. We believe the current study is the first within-subjects on-road high-dose double-exposure clinical-trial investigation of musical stimuli on driver behavior.

We acknowledge that the vehicles were foreign to the participants, and also there was an unknown adult present in the car. Hence, some might assume that the participants felt awkward, and perhaps attempted to behave as lawful as possible. Skeptics might even question the findings altogether. Yet, the current platform resembles driving lessons, and therefore we can assume that the research structure was not so alien. In fact, the findings reveal a high level of *concurrency* between the empirical driving experience and everyday driving. The participants felt 'comfortable' with positive moods, and perceived driver caution throughout. Actually, the fact that every participant committed several violations (i.e., deficiencies of permissible driving), indicates that while they may have attempted to perform as lawful as possible, their *best* performance was no more than neophyte driving skill reflecting teenaged traffic-related behavior.

Every participant pre-selected 12 music items. Over one thousand music exemplars were brought from home. Musicological analyses found that the most popular styles were dance-paced tracks with vocals sung or *rapped* in English. These pieces were reported to be *highly-similar* to the music listened to in their own car, and were reproduced at *quite-similar* volumes as they usually hear when driving. Yet, when participants listened to the alternative music background they significantly decreased the volume.

Throughout, mood states were significantly more positive than negative. But, in trips with driver-preferred music brought from home the participants reported significantly increased positive affect, decreased negative affect, and levels of *enjoyment* as higher than any other driving condition. Such a finding confirms recently published reports by [van der Zwaag et al. \(2012\)](#) demonstrating that driving without music or with pieces perceived as 'negative' causes lower 'RR' (a physiological measure linked to arousal). We might assume, then, that the reported elevated levels of enjoyment may have something to do with over stimulation.

5.3. Performance measures

Scores from the *Young-Novice Driver Deficiency Rating Scale* indicated that only 12% (or 61-out-of-510) trips were fully efficient. Such a find means that every participant committed an average of three driving deficiencies in one or more trips. The data demonstrate that in trips with driver-preferred music brought from home there were the highest number of observed deficiencies, at the most severe levels of risk, requiring significantly more verbal interventions and physical manipulations than in either trips without music or in trips with an alternative music background. Throughout the study the six most prominent driver deficient driving behaviors were: speeding, maintaining attention, keeping the appropriate following distance, lane use, overtaking vehicles, and one handed driving. These six deficient behaviors are also listed by [Braitman et al. \(2008\)](#) as characteristic deviations of young-novice drivers. We find it interesting to note that the incidence of these deficiencies and violations were significantly decreased for trips with an

alternative music background – to even lower levels than when driving without music.

The study employed a research-tailored customized analysis application for IVDR data; the raw data stream was reduced to 27 events and maneuvers pertaining to driver behavior and vehicular performance. With these we calculated scores for event-frequency and event-severity. Accordingly, in trips with driver-preferred music brought from home the highest frequency of events at the most severe levels of risk were demonstrated. Such differences were consistent even when post hoc analysis targeting power-driven RPMs were implemented; these findings indicate that the participants were 50% more *aggressive* with their vehicles in tips accompanied by the music they prefer to drive with. By triangulating ratings of expert observers with IVDR-derived driver profiles, we note that 1-in-5 participants exhibited a driving style that, surely without the presence of an expert adult to physically intervene as a countermeasure, they might have been involved in an accident.

5.4. Individual differences

In general, we did not find individual differences that mediate the effects of music on driving behavior. Both genders were equal in the amount and type of music brought from home, driver-adjusted music volumes, level of music enjoyment, and overall mood. However, female drivers did report a higher level of perceived caution (for trips with their preferred music brought from home), as well as reported to be more aware of the alternative music background. On the other hand, male drivers committed an increased number of severely deficient behaviors in all driving conditions, and were more often classified as aggressive drivers.

Drivers with higher impulsivity sensation-seeking traits perceived the music they brought from home to be different than what they usually drive with, as well as the volumes they adjusted in the study. They also reported an increased negative affect, decreased enjoyment, and lower level of perceived caution for all trips not accompanied by their preferred music (but yet, they actually demonstrated the highest level of deficient driving behaviors in trips with preferred music brought from home). It is not surprising, then, that high-*ImpSS* participants were more often found among the *aggressive* driver subgroups in all conditions.

6. Conclusion

We feel that *in-cabin listening* provides optimal conditions for distraction that can result in driver miscalculation, inaccuracy, driver error, traffic violations, and driver aggressiveness. In a most recent review and meta-analysis by Young and Salmon (2012), driver error and distraction were seen to be highly related to one another, with overall estimates that these are a causal factor in 75–95% of road crashes. Further, they suggest that secondary task distraction is a contributing factor in at least 23% of all accidents. We would suggest that listening and/or singing to music is such as secondary task. But, not all music causes the same ill-effects, and some may even contribute toward increased driver safety. Thus, perhaps we might view the alternative music background as a form of self-mediated intervention (Brodsky and Kizner, 2012). The time is ripe to raise public awareness on the effects of *in-car listening*. Drivers must be educated about choosing music more wisely as listening to music in the car will not be given up simply because it may place drivers more at risk. Cars are here to stay, and *in-car listening* will forever be part of the driving experience.

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