"Please Don't Stop the Music..."

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“Please Don’t Stop the Music…”

The Influence of Music and Radio on Cognitive Processes, Arousal and Driving Performance

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“Please Don’t Stop the Music…”

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Table of Contents

Chapter 1

General Introduction

Music accompanies a variety of activities in daily life. We hear music while doing shopping, eating in restaurants, doing exercise in the gym, and on TV. We hear music in the waiting rooms or on the phone while on hold. We even hear music on streets if we were to pass by a street performer. Additionally, we not only passively hear music, but also actively listen to music of our own choice in different contexts. One such context that is highly associated with listening to music or the radio is driving.

Listening to music and the radio are indeed the most common auditory stimuli that drivers are exposed to on the road (Stutts et al., 2003; Dibben & Williamson, 2007). A large-scale survey carried out in Britain revealed that about 75% of drivers listen to music or the radio (Dibben & Williamson, 2007). Similarly, an on-road observational study carried out in the US revealed that music or radio-listening is quite common among drivers, and the driving task is accompanied by either radio or music listening 71% of the time (Stutts et al., 2003). In addition, drivers hold quite positive attitudes towards listening to music while driving (North, Hargreaves & Hargreaves, 2004; Patel, Ball & Jones, 2008). Specifically, they think of listening to music as a habitual in-vehicle activity that helps to kill time on the road (North, et al., 2004). The majority of drivers also believe that listening to music or the radio do not impair driving performance, and is not as distracting as other types of in-vehicle distracters such as talking to passengers (Dibben & Williamson, 2007). However, is that really the case? Are drivers able to perform well while listening to music or the radio? Does music/radio improve or impair driving performance? And if so, which aspects of driving performance and in what kind of driving environments? Moreover, through which processes does music/radio influence driving performance? These are the main research questions that we[1] are going to investigate in the current thesis.

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[1] As all the studies described in the current thesis have been carried out in colloboration with my promoters Linda Steg and Kai Epstude, and with the co-authors Samantha Platteel (Chapter 3) and Dick de Waard (Chapter 4), I use the term “we” instead of “I” throughout the dissertation.

We will explore the research questions in three empirical chapters. Before describing the content of the chapters, we will discuss the theoretical background of the studies. We will first discuss the cognitive, affective and behavioral consequences of listening to music. Next, we will elaborate on how music and radio listening influence task performance in the specific field of driving.

Cognitive, affective and behavioral consequences of listening to music

Music is a stimulus that is as ancient as humankind, and it is broadly defined as the organization of sound (Levetin, 2007). Music, yet, is not a simple stimulus to examine. It consists of many different structural properties such as pitch, tempo, mode, rhythm and harmony that interact and can be combined in many different ways, which might make a difference in terms of what is expressed with the sound (Gabrielsson, 2001). The experiences that are induced by music can also be quite diverse, varying from highly intense emotional states to physiological responses, such as increases in heart beat or having shivers (Gabrielsson & Lindström Wik, 2003). As a result of such experiences, music might have an influence on cognitions, feelings and behaviors.

Gabrielsson and Lindström Wik (2003) list the commonly observed cognitive consequences of listening to music as focused attention on music by abandoning other thoughts, being a whole with music, having imagery of different situations that are reminded by music, and having memories that are associated with music. Therefore, listening to music might alter thoughts, guide attention on specific musical qualities and trigger memory processes as well as suppress processing of thoughts that are not related to music.

Music might have a direct effect on emotions as well, and therefore affect mood states (Juslin, 2000). Supporting this argument, research suggests that individuals commonly use music to counter bad mood (Thayer, Newman, & McClain, 1994) as well as to intensify their current negative or positive mood (Saarikallio & Erkkilä, 2007). Specifically, some aspects of music are associated with different emotions or mood states (Gabrielsson & Lindstrom, 2001). For instance, while fast melodies are used to convey excitement, complex and atonal melodies are used to convey anger (Thompson & Robitaille, 1992). So, it has been suggested that by manipulating specific aspects of music, one can successfully induce specific emotions in the listener, varying from broad emotional states like happiness and sadness to very specific ones such as confusion, terror, wonder or despair (Gabrielsson & Lindström Wik, 2003).

The behavioral consequences associated with music-listening are, for example, a need for jumping, moving, tapping fingers, singing, dancing, smiling or freezing and unable to carry out any other activity in parallel to listening to music (Gabrielsson & Lindström Wik, 2003). So, music has a direct effect on behaviors, and might lead to dropping other tasks at hand if the listener is totally absorbed by music.

Apart from cognitive, affective and behavioral consequences; it has been suggested that music might also lead to very specific experiences such as transcendence and a shift in time and space perception by losing contact with reality (Gabrielsson & Lindström Wik, 2003), meaning that music-listening might lead to exclusive experiences. However, do we experience all the above-mentioned cognitive, affective, behavioral and exclusive effects whenever we listen to music? Findings suggest that whether the observed effects would take place depend largely on the context of music-listening, and particularly on whether other tasks accompany music-listening (Scherer & Zentner, 2001; Konečni & Sargent-Pollock, 1976). For instance, listening to a concerto in an opera house might facilitate various emotional responses in the listener while the very same music excerpt would lack inducing any emotions in another context where careful attention to the music is not possible (Scherer & Zentner, 2001). Similarly, both the behavioral effects like dancing or clapping hands and cognitive consequences such as abandoning oneself from outer world might not take place if the individual is restricted to work on other tasks while listening to music. In the next section, I will elaborate on how the context of music-listening might affect the way we feel, behave or process information as well as the way we perform on tasks accompanying music-listening.

Context of music-listening: When music-listening is not the main task but the accompanying task

In the majority of situations music-listening takes place in environments in which we are busy with other tasks, and music remains as a background stimulation while we are working on those tasks. The context or the environment where the listening takes place is therefore important in predicting to what extent the above-mentioned effects of music would be experienced. Imagine a situation, for example, where an air-traffic controller listens to a song on the radio while trying to manage landings and take-offs in an airport. At the very same time, a trainer working in a gym and whose task is to teach people how to use the training equipment is listening to the same radio-station and the exact same song. For whom would it be more possible to have a moment from their main tasks and pay attention to the song? For the air-traffic controller, it would be quite costly to have exclusive experiences with music while trying to manage the coordinates of planes which are in a row to land on the airport safely. The trainer, however, might close his eyes for a brief moment and experience all kinds of escape feelings without risking any decrements in performance. This example demonstrates that although music characteristics are important in inducing any kind of experience in the listener, when listening to music or the radio is not the primary task but only the accompanying task, then the primary task's characteristics are highly important in predicting how listeners respond to music and to what extent they pay attention to it. Yet, since music is associated with cognitive, emotional and behavioral responses, understanding how performance on the main task is influenced by this powerful auditory stimulus is highly important.

Scholars investigated the effects of music on main tasks in relation to probable negative or positive behavioral outcomes for performance (Kirkpatrick, 1943; Smith, 1961; Fontaine & Schwalm, 1979; Davies, Lang & Shackleton, 1973; Etaugh & Michals, 1975; Parente, 1976; Davenport, 1972; Cassidy & MacDonald, 2007). There is preliminary evidence indicating that arousing music (e.g. loud or rhythmic) might improve performance in tasks that are not extremely demanding but that need to be vigilant, such as detecting signals on a computer-screen (Fontaine &

Schwalm, 1979; Davies, Lang & Shackleton, 1973). Similarly, music was found to facilitate performance in automatic tasks that do not require much thinking, such as repetitive manual tasks (Husain, Thopmson, & Schellenberg, 2002; Fox & Embrey, 1972). In tasks like recall or reading comprehension that need more concentration and cognitive effort, however, music was found to distract individuals and inhibit performance on the main task (Kirkpatrick, 1943; Cassidy & MacDonald, 2007). Taken together, these findings suggest that music as an auditory stimulus can be quite distracting for some tasks while can be handled well and might even benefit performance for some other tasks. Importantly, whether the task is simple (low in difficulty and demands) or complex (high in difficulty and demands) seems to make a huge difference in predicting how music influences the performance during the execution of tasks (Konečni & Sargent-Pollock, 1976; Davenport, 1972, Fox; 1971).

Within the scope of this thesis, we are mainly interested in the influence of listening to music and the radio as a task accompanying the primary task of driving. In the following section, we will tell about the task characteristics specific to driving in understanding whether it holds the characteristics of a high-demand or low-demand task, and how music interacts with these characteristics to influence driving performance.

Driving task and context of driving

Driving has been commonly referred to as a perceptual-motor task that is self-paced (Brown, 1982), meaning that drivers implement certain actions based on perceptual cues prevalent in the traffic environment. For instance, the presence of an object on the road (a visual cue) necessitates a braking action or the careful maneuvering of the steering wheel to avoid a possible crash. Similarly, the perceptual auditory cue of hearing another car’s horn necessitates the action of checking the mirrors, which might then lead to several other actions, such as accelerating or decelerating. In general, the timely and accurate implementation of specific behaviors (e.g. steering the wheel, accelerating, checking the mirrors etc.) is how task-performance is defined in the context of driving. For example, the behavior of braking might need to be done relatively faster when confronted with a risky situation, and brake time can be used as a performance indicator to check whether the driver performed good or bad in managing the situation.

It has been suggested that drivers gain mastery on basic car-control skills and which action to implement in response to what type of stimuli by means of experience (Gregersen & Bjurulf, 1996). Some components of driving indeed develop rapidly by simple exposure and become highly automated, which then need little processing effort to be accomplished. For instance, while shifting gears or checking mirrors might be difficult tasks for a novice driver, an experienced driver carries out these tasks more easily (Shinar, Meir & Ben-Shoham, 1998). Indeed, when drivers are exposed to different traffic situations over and again, they are expected to develop a schema of driving which then, hypothetically, would guide them in action selection (Underwood, Chapman, Bowden, & Crundall, 2002). This highly behavioristic description of the driving task based on a stimulus-response approach, however, runs the risk of presenting the driving task as an easy task in all circumstances (cf. Groeger, 2000), because it implies that as long as the driver has a fully-developed schema of driving, the driving task would be well executed. Importantly, the definition does not take into account the influence of contextual variables on driving, such as the presence of distracters or the complexity of the traffic environment. These contextual factors might fiddle with the action-selection strategies by means of their influence on cognitive resources, such as by diverting attention on other driving-unrelated tasks (e.g. listening to music). As such, when the context imposes high demands, response latencies or delays can be observed even while executing highly automated aspects of driving, like mirror-checking (Brookhuis, De Vries, & De Waard, 1991).

For instance, consider a situation where a cheerful driver is listening to his favorite album while driving on an almost empty highway. The driver is singing along to music with joy, while at the same time managing the car-control with great precision. Now imagine that another car drove off from a joining road and emerged in front of the cheerful driver. Several decisions should be made with a precision of seconds or even milliseconds in such situations. The driver might decide to brake hard in order to avoid a crash with the car ahead, but to do that he should first check whether there is a car behind in a close distance to his vehicle. If there is a car behind that is very likely to crash the cheerful driver's car if he or she engages in a hard brake, then the driver should consider swerving to right or left. Is there enough space on the right or left? Are there any other vehicles or objects on the sides of the road? The driver's favorite album is still filling the air in the car, but the driver might not even hear it anymore, let alone singing along to it. As this example points out, the driving task involves low-complexity and high-complexity situations following each other, usually in an unpredictable order. As such, task-difficulty and demands related to driving change continuously in a regular trip based on changing contexts while driving. For instance, drivers might perceive driving as a simple and even boring task when they need to implement the same learnt actions over and again in a monotonous environment (e.g., car-following), while they might perceive it as a complex task when they are overloaded with stimuli and hazardous traffic incidents. Therefore, the experience of listening to music or the radio can also be quite different depending on the complexity of traffic and driving task. That is why it is crucial to investigate the influence of music and the radio on driving performance with reference to the complexity of traffic.

Listening to music or the radio in high-complexity and low-complexity traffic settings

Task demands experienced while driving are heavily affected by the road environment (e.g. a busy residential road), and the presence of and interaction with other road users in that environment (Fuller et al., 2008). For instance, high-complexity traffic environments typically involve driving in hectic city traffic in which drivers need to attend multiple variables at the same time, such as road signs, traffic lights or the movement of other vehicles (Jahn, Oehme, Krems, & Gelau; 2005). Low-complexity traffic situations, however, typically involve driving on rural roads in which drivers are exposed to less number of stimuli (Jahn et al., 2005). Importantly, when traffic complexity is high, drivers have a higher perceptual and cognitive load that necessitates them to regulate their attentional resources carefully (Strayer, Drews, & Johnston, 2003; Cantin, Lavalliére, Simoneau, & Teasdale, 2009). In such situations, the presence of an additional stimulus (e.g., music) might overload drivers by competing for the cognitive resources needed to execute the driving task, and compensatory actions might be needed to cope with the overload and distraction induced by additional stimuli (Hockey, 1997; Cnossen, Meijman & Rothengatter, 2004). Task-demands, however, might also increase when traffic-complexity is extremely low (Wertheim, 1991). When complexity is low, driving task might become overly dull, leading to adverse feelings such as boredom or sleepiness. In such situations, the presence of music or the radio might help to reduce boredom or sleepiness by arousing drivers and providing them with the necessary stimulation to stay vigilant.

So, both high and low complexity situations might be cognitively demanding for drivers. However, the presence of music or the radio might influence driving performance differently in high and low-complexity settings. In the following section, we will elaborate on the specific processes through which music or the radio influences performance or helps to maintain a desired performance level in high and low-complexity traffic settings.

Music and radio-listening in high-complexity traffic: Employing compensatory strategies

Driving in high-complexity traffic necessitates drivers to manage various critical incidents resulting from sharing the road not only with other vehicles, but also with cyclists and pedestrians. The abundance of critical or hazardous traffic incidents might increase task-demands and feelings of task-difficulty while driving (Fuller, et al., 2008). Interestingly, in simulated driving studies that allow for measuring driving performance in close-to-real-life experiences, traffic complexity or task-demands has been rarely taken into account or manipulated in studying the influence of music or the radio on driving performance (see Hughes, Rudin-Brown, & Young, 2013, for an exception), while there were attempts to manipulate not the complexity but the road-infrastructure to increase task-demands (e.g., using curvy roads or narrow lanes; Van der Zwaag, Dijksterhuis, De Waard, Mulder, Westerink, & Brookhuis, 2012; Jäncke, Musial, Vogt, & Kalveram, 1994). Specifically, in the majority of the studies that focused on music, scholars manipulated music characteristics in an attempt to increase task-demands instead of manipulating task characteristics (Brodsky, 2002; Pêcher, Lemercier & Cellier, 2009; North & Hargreaves, 1999). For instance, Brodsky (2002) examined the influence of different tempi on driving performance measured by speed, lane violations and red-light violations. The driving task involved having several laps on a ring-road in a traffic environment that involved no other vehicles but pedestrians as road-users. Results revealed that lane violations increased as the tempo of music got higher, indicating that high-tempo might impair car-control skills. In another study, Pêcher and colleagues (2009) tested whether happy or sad music would influence driving performance differently. The results revealed that happy music led to adopting lower speeds and impaired lateral control. In addition, drivers were found to exhibit behaviors like tapping the fingers on the steering wheel while listening to happy music, which lead the authors to conclude that happy music might divert attention away from the driving task. However, since both studies consisted of driving straight ahead and no interaction with other vehicles, one wonders whether a degradation in some aspects of performance would still be observed if more demanding traffic conditions had been simulated or if task-demands had been higher due to driving-related characteristics. Then, how is driving performance influenced in high-demand conditions?

In one of the few studies that aimed at increasing task-demands by manipulating driving-related aspects during simulated driving, such as the road infrastructure, it was found that music had no influence on lateral control of drivers (Van der Zwaag et al., 2012). Importantly, this was observed both in high task-demand (driving on a narrow lane) and low task-demand conditions (driving on a wide lane). In addition, music was even found to facilitate lateral-control when the simulated task consisted of hazardous incidents that necessitated the careful monitoring of the traffic environment (Hughes et al., 2013). Together, these findings indicate that the presence of music does not necessarily impair performance (and specifically car-control skills) in more challenging traffic settings. Interestingly, Van der Zwaag and colleagues (2012) interpreted their findings as the music they used being not demanding enough to interfere with driving performance in high-demand traffic settings. This argument suggests that when both listening demands and task-demands are high, then driving performance would be most likely to impair, which begs the question whether it would really be the case.

There have not been many attempts to examine the interaction of music and driving task characteristics thoroughly in simulated driving studies. In a study that employed a driving game console rather than a simulator, researchers compared perceived task-difficulty while playing the game in different conditions varying in cognitive demands (North & Hargreaves, 1999). It was found that perceived task-difficulty was higher when high arousing music (high volume - high tempo music) was played as compared to when low arousing music (low volume –low tempo music) was played. The finding was interpreted as arousing music being more demanding to listen to compared to a low-arousing music. Importantly, task-difficulty was the highest when the driving task was accompanied not only by high arousing music but also by working on a secondary task of backward counting. Drivers were also found to have the longest laps (as an indication of speed) in this last condition, meaning that a perceived increase in difficulty and demands led drivers to decrease their speed in an attempt to have better control over the car-control equipment. Despite the fact that demands were increased by the addition of a third task instead of manipulating driving-task characteristics, the findings of North and Hargreaves (1999) suggest that listening demands might indeed contribute to task-difficulty especially when drivers are somewhat cognitively overloaded, and might lead drivers to exhibit compensatory behaviors such as decreasing their speed. So, drivers might seek for ways to deal with the cognitive load induced by other tasks such as listening to music by prioritizing the driving task that is of primary value to them due to driving safety.

Can we observe similar results in relation to radio-listening? As indicated earlier, radio-listening is quite a common activity among drivers (Dibben & Williamson, 2007; Stutts et al., 2003), and it differs from music-listening in terms of the variety of auditory stimuli it involves, such as news reports, talk-radios or commercials. Interestingly however, how radio-listening interacts with complexity of traffic or task-demands has not been examined thoroughly either. In one particular study which included a simulated world consisting of hazardous incidents, listening to the radio (i.e., talk-radio and music) was found to have no detrimental effects on driving performance (Hatfield & Chamberlain, 2008), suggesting that despite the relative complexity of traffic, driving performance was secured when drivers listened to the radio. The authors explained their finding based on the reasoning that radio-listening is habitual among the majority of drivers, and therefore, does not interfere with driving performance, regardless of the different audio-material used. In other studies, scholars generally tested effects of radio listening on performance on computer-based tasks (i.e., reaction time based tasks signal detection or pursuit tracking; see Strayer & Johnston, 2001; Consiglio, Driscoll, Witte, & Berg, 2003). These studies however, compared effects of radio-listening to effects of mobile phone conversations on performance. More specifically, such studies had the purpose of identifying whether listening to speech on the radio (such as news or interviews) would affect performance differently than listening to someone on a mobile phone; the latter was expected to characterize a more engaging listening context than the former. The findings supported this expectation, and suggest that listening to the radio did not impair reaction times to signals, while talking on a mobile phone did affect performance negatively (Strayer & Johnston, 2001; Consiglio et al., 2003). Hence, it was concluded that radio-listening is indeed not as engaging as listening to a personally relevant conversation on a mobile, as it requires lower involvement with the auditory stimuli. Importantly, even when engagement was increased by having participants carefully attending to a broadcasted audio book, drivers' reaction times to signals were still not impaired compared to that of when talking on a mobile phone (Strayer & Johnston, 2001). This latter finding suggests that drivers were able to secure their performance while listening to the radio.

These interpretations regarding how music or the radio might be handled while driving are indeed supporting theoretical predictions on task-prioritization as an efficient way to deal with demands induced by other tasks or stimuli that are unrelated to the main task (Kahneman, 1973; Hockey, 1997). Specifically, performance maintenance by engaging in task-prioritization in demanding situations was hypothesized to be achieved by employing cognitive compensatory strategies; namely regulation of mental effort and regulation of attentional resources.

Regulation of mental effort

Mental effort has been defined as the measurable component of mental workload, which reflects the processing demands that the operator experiences at any moment while working on a task (Kahneman, 1973; Mulder, 1980; De Waard & Brookhuis, 1997). Mental effort is expected to increase when individuals are working on concurrent tasks or when there is a distracter, such as music, accompanying the main task and which uses the same resources as the main task (cf., De Waard, 1996). But, what does an increase in mental effort represent in dual-task conditions or when we are distracted?

In his model on compensatory control, Hockey (1997) argues that an increase in mental effort reflects the presence of a cognitive strategy which is used to prioritize the primary task performance over distracters or secondary task. Specifically, Hockey (1997) posits that task-prioritization would always favor the main task with the highest importance. In order to secure performance on the main task, individuals need to actively cope with the additional load induced by a secondary task or a distracter. According to the model of compensatory control, one way to cope with additional demands is through putting more effort on the primary task, which can simply be measured by mental effort. So, when the primary task is accompanied by another stimulus, an increase in mental effort might suggest that the task-performer is trying harder to compensate for the distraction (or load) induced by the additional stimulus.

Interestingly, studies that focused on music did hardly ever provide evidence for the existence of an effort-based regulatory control taking place while driving and listening to music. For instance, listening to music that induced positive or negative mood had no influence on mental effort neither when driving on narrow lanes nor on wide lanes (Van der Zwaag et al., 2012). This indicated that music can still be handled well in conditions of higher task-difficulty induced by road-infrastructure. Listening to music was not found to increase perceived demands and mental workload in a short simulated drive either, indicating that workload is not affected by music at least when driving for a shorter period (Huges et al., 2013). Also, Brodsky (2002) found no differences between the influences of different tempo levels on mental effort, and only reported a significantly higher level of mental effort when he combined all tempo conditions and compared it to a baseline condition with no-music. As the combination of three conditions was also reflecting the mental effort over a longer period of driving, it is not possible to conclude whether the observed increase was due to longer exposure to music or longer exposure to a driving task that was based on driving straight ahead.

So, findings that examined the relationship between listening to music and mental effort are inconclusive. However, we believe that this can be partly due to having no manipulations regarding traffic complexity or demands related to the driving task. For instance, unless drivers perceive the driving task demanding or difficult, they might not feel the urge to prioritize it, as there would be no realistic threats to driving performance. As such, it is important to find out how music influences mental effort in settings that are close to real-life driving, where drivers are exposed to both high-complexity and low-complexity traffic settings and where they come across to other road-users. Therefore, in Chapter 2 of this thesis, we will examine whether driving performance can be secured by investing more mental effort on the driving task while listening to music in a rather complex traffic environment consisting of various critical incidents as well as some low-complexity situations (e.g., monotonous driving).

Regulation of attentional resources: More to the primary task and less to the secondary task

As discussed earlier, a compensatory strategy based on the regulation of mental effort might indicate that drivers are trying harder not to fail the primary task of driving. But, what does it mean to try harder? What do drivers do precisely to secure their performance which then reflects on their mental effort? Kahneman (1973) proposed that an increase in mental effort indicates a process of "resisting to distraction" (p.118). According to his theory of attention control, resistance to distraction can only be achieved by allocating more attention on the primary task rather than a secondary task or a distracter. As such, the limited cognitive resources are allocated on tasks based on the importance of tasks, and performance on tasks that are not assigned much importance might simply impair for the sake of the task that has utmost priority (Kahneman, 1973; Hockey, 1997). Therefore, a possible way to measure whether increased mental effort indeed helps to secure the primary task performance is to check whether secondary task-performance has been impaired while the primary task performance remained intact or even improved.

Findings of previous research on multitasking while driving provided initial support to the existence of a strategy based on controlled-attention allocation in the presence of distracters and secondary tasks (Wester, Bocker, Volkerts, Verster, & Kenemans, 2008; Drews, Pashupati, Strayer, 2008; Cnossen, Mijman, & Rothengatter, 2004). For instance, when drivers had to deal with a secondary auditory task, they were found to regulate their attentional resources in such a way that they avoided the processing of driving-unrelated auditory stimuli presented during the secondary task (e.g. animal sounds; Wester et al., 2008). This also helped them to maintain the primary task performance, which was measured by the steering wheel control. Similarly, drivers were found to decrease their talking pace and the complexity of their speech when confronted with demanding traffic situations (Maciej, Nitsch, & Vollrath, 2011; Crundall, Bains, Chapman, & Underwood, 2005), indicating that tasks that are irrelevant for driving safety were given less priority. Do drivers use a similar strategy when listening to music or the radio and driving?

To our knowledge, there has not been any attempt to examine whether drivers engage in task-prioritization by paying less attention to the music or radio while driving. It has not been tested whether drivers allocate their attention on music or radio differently in high-complexity and low-complexity settings either. So, in Chapter 3 of this thesis, we aim to study to what extent drivers pay attention to a radio program when confronted with hazardous driving incidents versus when driving in a low-complexity and hazard-free environment.

In the first two empirical chapters, we aim to broaden our understanding on how auditory distraction created by music or the radio is handled by drivers, especially while driving in environments that are already cognitively demanding. Yet, it is also within the scope of this thesis to find out the changes in driving performance in the presence of music while driving in environments that are predominantly monotonous. Therefore, in the next section, we will elaborate on the specific processes that might be relevant for conditions that involve music-listening in very low-complexity traffic; namely arousal and activation.

In low-complexity traffic: Arousal and activation

Driving does not always take place in high-complexity traffic environments but also in low-complexity traffic environments. While high-complexity traffic is marked by an abundance of stimuli, low-complexity traffic is marked by the absence of sufficient number of stimuli. At the very first glance, we might think that one should prefer low-complexity traffic over high-complexity traffic, because the latter is associated with higher demands and task-difficulty compared to the former. Interestingly, drivers might also feel a higher task-difficulty when driving in low-complexity settings, such as monotonous driving (for a detailed review, see De Waard, 1996). So, why do drivers experience such difficulty in low-complexity driving environments?

One of the reasons of increased task-difficulty in low-complexity traffic settings is related to drivers' experiencing adverse states such as boredom, sleepiness and drowsiness while busy with monotonous driving tasks (O'Hanlon, 1981; Wertheim, 1991; Nelson, 1997; Thiffault & Bergeron, 2003). As a result of these adverse states, drivers suffer from low-arousal and activation while driving in such contexts. Having a low-arousal level due to the absence of external stimulation, however, can be detrimental for performance, as predicted by the Yerkes- Dodson law (1908).

Specifically, according to the Yerkes-Dodson law (1908; Hebb, 1955), the relationship between arousal and task-performance can be depicted as an inverted-U shape curve. When arousal level is too high or too low, task performance is predicted to impair. On the other hand, when arousal level is optimal, task-performance is predicted to enhance. Importantly, earlier scholars also made a distinction between how arousal interacts with task characteristics. It was argued that the optimal level of arousal should be higher for simple tasks and lower for complex tasks, meaning that for complex tasks the optimal level of arousal is negatively skewed while in simple tasks it is positively skewed as projected on an inverted-U shape (McGrath, 1963). This suggests that operators who are busy with simple tasks that take place in monotonous conditions have a higher need for arousal for the best performance attainment.

An explanation regarding how the arousal-performance relationship works was given by Easterbrook (1959) in his cue-utilization theory. Easterbrook (1959) argued that the principles behind the optimal need for arousal and performance can best be explained by the mediating role of attention, as arousal was defined as the fuel guiding attention. So, according to the theory, when arousal is too low, individuals might simply lose focus and are unable to attend the cues that are relevant for task performance. In other words, both focused and selective components of attention might impair as a result of low arousal. A high arousal level is also predicted to impair attention by making individuals focus on all kinds of cues without discriminating between the relevant and irrelevant ones. As such, attention would not work selectively leading individuals to work with a bombardment of stimuli that are not important for task performance. In explaining how the Yerkes-Dodson law works, a moderate and optimal level of arousal is expected to facilitate attention process the most, by helping individuals to focus on the relevant cues and neglecting the irrelevant ones.

Supporting the premises of cue-utilization theory, it has been argued that drivers might seek ways to satisfy their need for arousal in monotonous driving environments, such as by engaging with distracters or secondary tasks (Heslop, Harvey, Thorpe, & Mulley, 2010). There is initial evidence to suggest that the presence of distracters, such as talking on a mobile-phone, could even benefit driving performance in environments with very low external stimulation (Brookhuis, De Vries, & De Waard, 1991). Can music also act as an external stimulation source to benefit performance in monotonous contexts? Interestingly, this question has never been tested thoroughly by previous studies either. So, in Chapter 4 of this thesis, we aim to examine whether music will be able to provide drivers with an optimal level of arousal, and whether driving performance will indeed improve while listening to music in a low-complexity traffic environment.

The current thesis

The current thesis focuses on examining how music or the radio affects driving performance in high and low-complexity traffic settings, and via which processes driving performance is secured or even facilitated while listening to music. Specifically, by employing the two rather different driving contexts (which are relatively high and low in traffic complexity, respectively), we will try to establish whether traffic complexity indeed matters in influencing how drivers handle music or radio-listening while driving. We hypothesize that in high-complexity situations drivers make use of compensatory strategies while driving along with listening to music or the radio, such as regulating their mental effort or regulating their attentional resources (Chapter 2 and 3). We expect that in very low-complexity situations driving performance will be secured by another process, namely arousal, which would be triggered by the external stimulation provided by music (Chapter 4). Below, we will describe the aim of the empirical studies and the hypotheses addressed in each chapter.

Chapter 2: Does music affect mental effort and driving performance while driving?

In the first empirical chapter, we will explore how and to what extent driving performance is maintained while listening to music and driving in a rather complex traffic environment. As discussed earlier, when stressors or distracters accompany a task and compete for limited cognitive resources, a common strategy used by individuals is the regulation of mental effort (Hockey, 1997). An increase in mental effort indicates that drivers are trying harder to keep their performance at a desired level (De Waard & Brookhuis, 1997). By allocating more resources on the driving task, drivers might therefore secure their performance when they face distracters. In driving contexts, mental effort is not only influenced by the presence of distracters or secondary tasks, but also by the demands induced by traffic environment (Jahn, Oehme, Krems, & Gelau, 2005; Cantin, Lavalliére, Simoneau, & Teasdale, 2009). For instance, when the traffic complexity is high, drivers might need to put more effort on the task to manage the demands of the traffic situations. But, how would the presence of a distracter such as music interact with traffic complexity to influence mental effort and driving performance? Would music create the necessity to try harder not to fail the driving task while busy with situations that differ in complexity? Would music increase mental effort irrespective of traffic complexity? In the first empirical chapter, we will address these research questions to enhance our understanding on how auditory distraction is handled by drivers in a predominantly demanding traffic environment.

Following the earlier predictions that the primary task is always prioritized (Hockey, 1997; Kahneman, 1973), we first hypothesize that drivers would invest more effort in the driving task in the presence of music as compared to in the absence of music, meaning that music would add on the already existing cognitive load created by high-traffic complexity. So, we expect mental effort to be higher throughout the whole time while driving in a rather high-complexity traffic setting including different critical incidents and listening to music than while driving without music. Second, we hypothesize that drivers who listen to music will perform as well as the drivers who do not listen to music. So, we expect that regulating the mental effort will help music-listeners to secure their driving performance despite the extra load induced by music. Finally, we expect that if there are any improvements in performance in the presence of music, then this improvement will result from heightened mental effort. That is, mental effort will mediate the effect of music on performance.

Chapter 3: Do individuals block-out auditory distracters while driving?

In the second empirical chapter, we will explore how drivers prioritize the driving task while driving and listening to the radio, especially in high-complexity traffic situations. As proposed by Kahneman (1970) and Hockey (1997), lowering the criteria for secondary task performance by partly ignoring it is a common strategy used by individuals whenever the secondary task pose demands that are higher than can be handled by existing cognitive resources (Drews, Pasupathi, & Strayer, 2008; Maciej, Nitsch, & Vollrath, 2011). We propose that this strategy will also be applied while driving and listening to the radio. That is, listening to the radio as a concurrent auditory task can be ignored to a certain extent when drivers feel that the scarce cognitive resources should not be wasted on other tasks than driving. We call this process of paying more attention to the primary task of driving and less attention to the radio *blocking-out audio content*. We propose that the inclination to block-out audio content can be observed by measuring to what extent drivers recall the content of audio stimuli they have listened to on the radio. So, if drivers do not pay careful attention on the radio, the later recall of audio-content should be lower as compared to when they attend to it carefully.

We will test whether drivers indeed use blocking-out radio-content as a compensatory strategy while driving in two studies. In Study 1, we will measure how much of a radio-content is being blocked-out normally, when the radio-listening is not accompanied by the driving task, to examine to what extent individuals might block-out radio-content when the radio-listening takes place in more relaxed conditions (e.g., at home). So, in Study 1, we aim to obtain a baseline of blocked-out radio-content reflecting the amount of audio stimuli that remained unattended when there was no driving task involved.

In Study 2, we will use the same radio-content along with a simulated driving task. Among a sample of drivers, we will first test whether individuals would block out more of the radio content when they have the concurrent task of driving. That is, we will compare the amount of radio-content blocked-out by drivers to the amount of radio-content blocked-out by the baseline group in Study 1. We expect that listening to the radio will not be prioritized as a task by drivers due to the demands coming along with the driving task. Hence, we hypothesize that the amount of blocked-our radio content will be higher while busy with driving (Study 2) than while solely listening to the radio (Study 1).

The demands of driving are continuously changing, and task difficulty might be much higher in conditions of high traffic complexity (Stinchcombe & Gagnon, 2010; Baldwin & Coyne, 2003). Therefore, in Study 2 of the second empirical chapter, we will also explore whether the tendency to block-out radio-content differs depending on traffic complexity. Due to an abundance of information flow and high perceptual load prevalent in busy traffic conditions (Strayer & Johnston, 2001), we expect that drivers will pay attention to the radio the least when they need to execute the driving task in high-complexity traffic as compared to in moderately low-complexity traffic. To test this hypothesis, we will compare how much of radio content is being blocked-out in high-complexity and moderately low complexity traffic. Importantly, we propose that drivers who listen to the radio will perform as well as the drivers who do not listen to the radio. So, we assume that the strategy to block-out radio content is an effective strategy to keep driving performance on desired levels while listening to music or the radio, especially in high-demand traffic environments.

Chapter 4: Does music activate drivers in monotonous driving situations?

We discussed above that in challenging driving conditions drivers would use cognitive compensatory strategies to ease task-demands and maintain their driving performance while listening to music or the radio. In the third empirical chapter, we will explore the influence of music on driving performance in a low-complexity traffic setting when busy with a monotonous driving task.

Monotonous task conditions are marked by the lack of external stimulation where the operator might experience deactivation due to feelings of boredom, sleepiness or fatigue (Nelson, 1997; Thiffault & Bergeron, 2003). In such situations, drivers should monitor themselves continuously to stay vigilant, and fight against adverse driver states by allocating cognitive resources on the task. As such, the driving task might become more effortful and tiring, leading to a higher mental workload similar to in high-demand traffic situations. More importantly, lack of external stimulation, which is predictive of low-arousal state, might impair performance by inhibiting attention regulation (Kahneman, 1970; Easterbrook, 1959). As discussed earlier, when arousal level is too low, performing well on a task would be much harder because regulation of attention on task-related features would be impaired (Easterbrook, 1959, Yerkes & Dodson, 1908). Following from this assumption, we propose that in driving conditions in which drivers suffer from low-arousal states, the presence of music might actually boost up arousal closer to an optimal level. The increase in arousal might in turn enhance performance of a monotonous task. In the third empirical chapter, we will test these propositions by employing a car-following task that takes place in a monotonous and highly predictable traffic environment.

First, we hypothesize that music will not impair performance in a monotonous car-following task, and might even facilitate some aspects of the driving task. In other words, listening to music will either have no-effects or a positive effect on driving performance. As we explained above, we hypothesize that the maintained or even facilitated driving performance will result from a higher arousal level in the presence of music, as predicted by the Yerkes-Dodson law. Therefore, we will explore the influence of music on arousal and performance by employing two volume levels, namely loud and moderately loud music. By doing so, we aim to find out whether the effects of music would depend on loudness as well, which is a property of music that has been documented to be related to energy and arousal (Dalton, Behm, & Kibele, 2007; North & Hargreaves, 1999; Turner, Fernandez & Nelson, 1996). We hypothesize that loud music would induce higher arousal levels than moderately-loud music, and would enhance performance even more as compared to a condition with moderate loudness.

Lastly, as explained above, driving task might also be cognitively demanding when individuals are busy with a monotonous task (De Waard, 1996). In such situations, drivers might need to put more effort on the task to be focused on the road despite low levels of arousal that impairs attentional resources. As such, the presence of music, which is expected to increase arousal closer to optimal levels, might help drivers to experience a lower cognitive load as well, which would reflect on their mental effort. Based on this assumption, we expect drivers will invest more effort in the car-following task when they lack external stimulation. So, we hypothesize that mental effort will be lower in the presence than in the absence of music.

In sum, in three empirical chapters we aim at exploring how and to what extent music or the radio influences driving performance in high-complexity and low-complexity traffic settings. In Chapter 5, we will discuss the main findings of the empirical chapters and elaborate on the theoretical and practical implications of our results.

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Chapter 2

The Influence of Music on Mental Effort and Driving Performance

This chapter is based on Ünal, A.B., Steg, L., Epstude, K. (2012). The effects of music on mental effort and driving performance. *Accident Analysis and Prevention*, *48*, 271-278.

Abstract

The current research examined the influence of loud music on driving performance, and whether mental effort mediated this effect. Participants (N= 69) drove in a driving simulator either with or without listening to music. In order to test whether music would have similar effects on driving performance in different situations, we manipulated the simulated traffic environment such that the driving context consisted of both complex and monotonous driving situations. In addition, we systematically kept track of drivers' mental load by making the participants verbally report their mental effort at certain moments while driving. We found that listening to music increased mental effort while driving, irrespective of the driving situation being complex or monotonous, providing support to the general assumption that music can be a distracting auditory stimulus while driving. However, drivers who listened to music performed as well as the drivers who did not listen to music, indicating that music did not impair their driving performance. Importantly, the increases in mental effort while listening to music pointed out that drivers try to regulate their mental effort as a cognitive compensatory strategy to deal with task demands. Interestingly, we observed significant improvements in driving performance in two of the driving situations. It seems like mental effort might mediate the effect of music on driving performance in situations requiring sustained attention. Other process variables, such as arousal and boredom, should also be incorporated to study designs in order to reveal more on the nature of how music affects driving

1. Introduction

Imagine that you are driving in a very quiet neighborhood, listening to one of your favorite bands and singing along with the music. Suddenly you realize that you are approaching an intersection and the traffic is getting busy. There are traffic lights, pedestrians and other vehicles that you should monitor all at the same time to avoid possible accidents. You stop singing along, but the music is still playing. You may have encountered this kind of situation many times while driving, but what would you do?

Would you feel like the driving task is more effortful due to the music? Would you turn off the music? In this paper, we aim to explore to what extent music influences drivers' mental load and performance in different situations, and whether drivers are able to cope with task demands in the presence of music.

Driving is executed along with secondary tasks, distracters or stressors most of the time, such as talking to a passenger, tuning the radio, attending to irrelevant on-road stimuli like advertisements or talking on the cell-phone (Haigney, Taylor, & Westerman, 2000; Horberry, Anderson, Regan, Triggs, & Brown, 2005; Crundall, Van Loon, & Underwood, 2006; Drews, Pasupathi, & Strayer, 2008), all of which may significantly affect task demands and driving performance. Listening to music or the radio is among the most common auditory stimuli that drivers are exposed to on the road (Dibben & Williamson, 2007). Indeed, listening to music is often a habitual behavior that accompanies driving and is perceived as helping drivers to easily pass the time (North, Hargreaves, & Hargreaves, 2004). As a result of this habitual use of music, drivers seldom find music as distracting as talking to passengers or talking on the cell-phone, and therefore do not tend to perceive music as a distracter that would impair their driving performance (Dibben & Williamson, 2007). Do self-reports of drivers reflect the reality however? Or does music have an influence on mental load and task performance while driving?

In previous investigations of this issue, researchers have tended to use two main methods: computer-based tasks that measure variables related to driving skills (e.g. reaction-time, brake response time) or simulated driving tasks which allow for directly observing the impact of music on driving (Brodsky, 2002; North & Hargreaves, 1999; Beh & Hirst, 1999; Turner, Fernandez, & Nelson, 1996). In simulated driving studies, the focus has been mainly on general driving behavior parameters such as speed, rather than specific measures of driving performance such as brake response or reaction time. In one particular driving simulator study, music that was high in arousal potential (i.e., high tempo music played at a high volume) resulted in longer lap times and therefore decreases in speed as compared to music that was low in arousal potential (North & Hargreaves, 1999). In this case highly arousing music was also associated with a high processing demand, indicating the music was influencing driving behavior through an effect on cognitive resources and information processing. Similarly, a different study found that listening to happy music was related to decreases in speed, as well as a deterioration of vehicle-control measured by lateral positioning of the car in a simulated drive (Pêcher, Lemercier, & Cellier, 2009). It was suggested that high engagement with the music in the happy music condition distracted the participants to the extent that their attention was directed more on inner thoughts and feelings than on the road, resulting in impaired vehicle-control. However, contrary to these findings, Brodsky (2002) found that high-tempo music lead to increases in speed and red-light violations during a simulated drive. Brodsky (2002) also reported that the arousal level, measured by heart rate, was not related to changes in the tempo of the music. Therefore, in contradiction with North and Hargreaves (1999), Brodsky (2002) concluded that the effect of music on driving can best be explained by its potential to distract rather than its arousal potential. So, the findings derived from the studies on simulated driving are somewhat mixed, and there is little known yet about the processes through which music influences driving performance.

Music has also been found to have varying effects in computer-based tests of driving related skills. For instance, in a simple vigilance signal detection task, participants who listened to familiar music detected more signals than the participants who listened to non-familiar music (Fontaine & Schwalm, 1979). However, vigilance did not differ significantly between no-music and non-familiar music conditions. Since arousal was found to be the highest in the familiar music condition, this was interpreted as familiar music affecting vigilance levels through arousal, although this assumption was not tested empirically. In a similar computer-based task, Turner, Fernandez and Nelson (1996) compared the effect of music played at three different sound levels on signal detection. Neither low-volume (60dBA) nor high-volume (80dBA) music facilitated performance, but a moderate sound level of 70dBA resulted in faster reactions to signals. These results were interpreted as music being facilitative when listened to at amplitudes close to one's comfort level, which was around 72dBA for male participants and 66dBA for female participants. Moreover, the authors reasoned that loud music, which is demanding to listen to, had a negative influence on attention capacity, which therefore impaired the early detection of relevant signals. The overloading effect of a demanding type of music on information processing and attention resources has been supported by other studies as well. For instance, Dalton, Behm and Kibele (2007) found that loud music of 95dBA impaired sustained attention resulting in slower reaction and movement times in a vigilance task. Based on this result, the authors concluded that music competes for one's available cognitive resources, which results in a high mental load and processing demand while busy with another task, such as driving. Indeed, Beh and Hirst (1999) found that task demands might interact with the demands induced by music, potentially leading to differential effects on performance. In their study, Beh and Hirst (1999) compared the influence of no-music, along with low-volume and high-volume music on reaction time in a vigilance task in which participants had to respond to centrally and peripherally presented signals. In both music conditions, participants responded faster to the signals in the centre of the screen than participants in the no-music condition. There was no difference between the groups in reaction times to peripherally presented signals. However, when the task demands were increased by making the participants work on two other tasks (a stop-light task and a tracking task) while carrying out the vigilance task, high-volume music impaired the reaction times to the peripherally presented signals while low-volume music did not. Beh and Hirst (1999) interpreted their results by suggesting that at times of overload due to external stimulation (e.g. loud music), people tend to regulate their attention in such a way that they are focused on the task of primary importance, while their ability to allocate their attention to peripheral information or other tasks is temporarily impaired.

The above explanation is in line with Hockey's (1997) compensatory control model, which proposes that people regulate their attention and effort constantly to preserve primary task-performance at a desired level. Specifically, following Kahneman's (1973) theory of attention control, Hockey (1997) proposed that individuals allocate more resources to a primary task when there is a secondary task, a distracter or a stressor that is competing for shared cognitive resources, than when there is only a single task. Hockey calls this process as the energetical-control framework, and stresses that performance maintenance is "an active process under the control of the individual, requiring the management of cognitive resources through the mobilization of mental effort" (p. 78). In particular, Hockey (1997) proposed that we constantly regulate our effort based on the relative importance of the goals we have (such as succeeding in the primary task versus the secondary task), and changes in mental effort are representative of information processing, task-difficulty and the value of the tasks. Hockey argued that people constantly monitor their performance and, based on feedback on whether there are sufficient cognitive resources available, they try to adjust their resources to meet the current task demands. The adjustments in allocation of resources are done by relying on compensatory strategies such as increasing the mental effort to meet increased demands of the primary task or ignoring the secondary task.

Driving is a complex task, which if not carried out adequately can have serious safety consequences. So, do drivers also engage in compensatory strategies as to not fail the primary task of driving when the task demands increase? There is some evidence, based on simulated driving studies, showing that drivers employ behavioral compensatory strategies to handle the effects of distracters or secondary tasks (Young & Regan, 2007). At times of mental overload due to distracters and secondary tasks, decreasing the speed or increasing the headway with the lead car are among the common compensatory behaviors that drivers employ to make driving less demanding (Törnros & Bolling, 2006; Lansdown, Brook-Carter, & Kersloot, 2004; North & Hargreaves, 1999; Strayer & Drews, 2004). Besides behavioral adaptions, drivers also seem to use cognitive compensatory strategies such as the ones proposed by Hockey (1997). For instance, drivers were found to report higher mental effort when they were forced to drive at a speed that was lower than they would normally do, indicating that diverging from the habitual pattern of driving needs the regulation of mental resources to cope with task demands (Lewis-Evans, De Waard, & Brookhuis, 2011). Similarly, in the presence of distracters or secondary tasks, drivers reported higher mental load and effort, but they still maintained the primary task of car control and vehicle handling at a desirable level (Brookhuis, De Vries, & De

Waard, 1991). In short, drivers seem to adopt various strategies to allocate their cognitive resources to more important tasks or regulate their mental effort to meet increased task demands.

Can music have a similar impact on mental effort while driving? And if so, are drivers able to cope with the increased mental load and still perform well? In this study, we aimed to look at the influence of music on mental load and on a variety of driving performance measures that are relevant in different types of traffic situations. Our study differs from earlier studies on music and driving in three important aspects. First, previously simulator studies on the effects of music on driving performance have tended to focus on general indicators of driving performance such as speed, and did not focus on more specific criteria that are critical to driving performance such as reacting to unexpected events or brake responses to hazards. In this study, we aim to distinctively examine the influence of music on such performance measures as well. Second, in earlier simulated driving studies, the traffic environment was stable, and there was no fluctuation in the level of complexity due to traffic flow or other road users. However, the complexity of the traffic environment is a key factor increasing the mental load of drivers (Horberry et al., 2005). For instance, driving in high-density traffic is more challenging than driving in low-density traffic due to the abundance of information flow (Strayer, Drews, & Johnston, 2003; Baldwin & Coyne, 2003). In addition, critical situations such as hazardous events lead to an increase in mental load (De Waard, 1996). Therefore, given that contextual factors are likely to have an effect on feelings of invested mental effort, we simulated a broad range of critical events that differed in complexity during which participants were also exposed to music. Third, although previously researchers used mental load or information processing to explain why music impaired performance by acting as a distracter (North & Hargreaves, 1999; Brodsky, 2002), this explanation has not been explicitly tested. That is, the studies did not include a direct measure of mental load, nor did they assess the effect of mental load as a process variable to explain why music affects driving. In our study therefore, we included a measure of mental effort which is an indication of mental load and information processing and allows us to measure cognitive processes in a more systematic way.

Based on Hockey's (1997) compensatory control model, our first hypothesis was that music would induce an extra load on the driver in addition to that of created by contextual factors (such as hazardous incidents or high-density traffic), and that the extra mental load would be reflected in mental effort ratings. More specifically, we expected the drivers who listened to music would experience a higher mental effort level while driving as compared to drivers who do not listen to music, irrespective of the complexity of the traffic situation. Second, we expected that drivers who listen to music would still perform as well or even better as drivers who do not listen to music. In other words, we expected that drivers would hold their primary task performance at the desired level. Finally, we hypothesized that any difference in the performance levels between drivers who did and did not listen to music would be mediated by mental effort. That is, we expected that if music affects driving performance, this is due to changes in mental effort: music affects mental effort, which in turn influences performance. So, in line with Hockey's (1997) theory we expected that drivers would regulate their effort to compensate for the distracting nature of music.

2. Methods

2.1. Participants

Initially 74 psychology students who held a valid driving license participated in the study. However, five of the participants could not manage to finish the simulated drive due to simulation sickness. Therefore, the total number of participants was 69 (46 female, 23 male) whose age ranged from 18 to 31, with a mean age of 21.04 (SD= 1.96). Their mean driving experience was 2.92 years (SD= 1.90), and mean annual km driven in the last year was 5818.84 (SD= 11443.99). None of the participants reported having any hearing deficiencies.

2.2. Research Design and Procedure

To avoid any possible learning effects for the critical incidents used to assess overall driving performance, the current study employed a single factor between-group design with a music and no-music condition. Participants were randomly assigned to one of the two conditions. Participants in the music condition created their own playlists by selecting songs from a website called Grooveshark that covered a broad range of genres. The first reason to adopt this strategy instead of making everyone listen to the same type of music was to increase the ecological validity of the study, as our participants made a selection based on what they would usually listen to while driving. In addition, by employing this method we made sure that participants were familiar with the music they were listening to, so that any effects observed in mental effort would not be attributable to unfamiliarity with the music or to disliking the music they were exposed to. In addition, in order to check whether the music condition was similar to a real-life situation in which drivers listen to their preferred type of music, participants filled out a brief questionnaire after the simulated drive. Responses were given on a five points scale (1= totally disagree; 5= totally agree). Participants reported that they enjoyed listening to the music (M= 4.53, SD= 0.56), the music was similar to what they usually listen to while driving (M= 4.38, SD= 0.65), and they did not find the music boring (M= 4.79, SD= 0.41).

The volume of the music was set relatively loud in order to create a demanding listening situation, with a sound level of approximately 90dBA (with a variation between 85dBA and 95dBA based on the physical features of the songs). A digital sound meter was used throughout the whole music condition to control for loudness.

Upon arrival participants were given an informed consent form and an instruction booklet. The booklet provided participants with information on the mental effort rating scale (explained below) as well as the experimental procedure. Participants were told that the researcher could ask about their mental effort any time while they were driving and that they needed to report their mental effort verbally by saying out loud the number representative of the mental effort at that moment. Prior to the experimental simulated driving, all the participants completed a training session in the simulator that lasted around 10 minutes. Participants in the music condition had the training with their preferred type of music on the background. This training ensured that all the participants got used to the equipment and the task of verbally reporting their mental effort. In addition, during the training session we were able to identify the participants who had simulation sickness and were unable to carry on with the experimental session. The experimental simulated driving took approximately 35 minutes to complete. After the experimental simulated driving, all participants completed a questionnaire that consisted of items asking about demographics and background information, and they were debriefed about the research.

2.3. Dependent Measures

2.3.1. Performance Indicators

Participants drove in the University of Groningen Driving Simulator. The simulator was on a fixed-base and surrounded by three screens that provided a 180-degree view of the road environment. The cabin looked like the inside of a car and had all the usual car-control equipment. All data on driver performance was automatically recorded throughout the drives in the database of the main computer at a sample rate of 10 hz. This allowed us to make detailed analysis of different segments of the road (see Van Wolffelaar & Van Winsum, 1995 for a detailed description).

For the current study, we created a simulated world featuring a regular driving context for the Netherlands that included 11 traffic incidents. We used a variety of road types such as residential roads, intercity roads and rural roads. Nine of the incidents were hazardous in nature, designed specifically for the purpose of creating conflict situations in traffic, and we called them as “critical incidents”. Six of these critical incidents took place in residential areas which consisted of heavy traffic, other cars violating the rules and several go/no-go type of situations such as traffic lights turning red. More specifically, the critical incidents that took place in the residential roads were: 1. car coming from the right, 2. car coming from the left and violating the give way rule, 3. a parked car suddenly pulling out (two times), and 4. gap acceptance at an intersection 5. gap acceptance at a T-junction. The remaining three critical incidents, which took place on intercity and rural roads, were 1. merging with the traffic on a highway, 2. traffic pile-up on a highway, and 3. traffic jam on a highway. In addition, for the intercity and rural roads, we included two driving situations that were not critical in nature, and which took approximately five to six minutes each: 1. car following, and 2. monotonous driving. All participants encountered all of the critical and non-critical incidents, and in the same order.

The simulator recorded the relevant performance indicators for all incidents. These performance indicators were brake response to hazardous situations, maximum deceleration during the incidents, time-headway to the lead car, time-to-contact with the lead car, lateral positioning and speed. Appendix gives a full description of all the incidents, driving situations and performance indicators.

2.3.2. Mental Effort

The Rating Scale Mental Effort (Zijlstra, 1993) was used to measure self-reported mental effort experienced at a given moment. The scale is unidimensional and participants simply indicated their mental effort on a scale ranging from 0 to 150 (0= no effort, 150= extreme effort). In a series of studies Zijlstra (1993) demonstrated that the scale is sensitive to changes in task load and correlates well with physiological changes based on task difficulty. Therefore the scale is a valid and reliable measure for subjective ratings of mental effort, and an indicator of workload and information processing during the execution of a task.

Participants reported their mental effort 13 times during the course of simulated driving: shortly after they started to drive (baseline measure), after each critical incident, during the two non-critical incidents, and at the end of the drive (end measure). More specifically, the baseline mental effort was measured after participants simply had been driving straight ahead for one minute, and therefore there was no incidents preceding the baseline measure. Following the baseline measure, participants were asked to report their mental effort right after every critical incident (e.g. parked car suddenly pulling out). As the non-critical incidents of car following and monotonous driving took longer to complete, we asked the participants to report their mental effort in the middle of the car following and the monotonous driving tasks, rather than at the end. Finally, participants reported their mental effort approximately 30 seconds before the end of the simulated driving which was labeled as the end measure. The mental effort ratings obtained during the experimental drive were immediately recorded by the researcher.

3. Results

3.1. Mental effort ratings

A mixed ANOVA was used with the mental effort ratings for driving situations as a within subjects factor and music as a between groups factor[2]. There was a significant main effect of the type of the driving situation on mental effort (F (12,732) = 30.33, p < .001) suggesting that we succeeded in simulating situations that required different levels of mental effort. More importantly, as expected, there was also a significant main effect of music on mental effort (F (1, 61) = 11.76, p < .001) while the interaction effect of music and type of critical event was not significant. Contrast statistics revealed that, in line with our expectations, the mental effort ratings of the music group were systematically higher than that of the no-music group (F values ranging between 4.90 and 14.26, all being significant at p < .05), irrespective of the type of the critical situation (see Figure 1).

[2] The parametric assumption of normality was checked separately for the music and no-music groups. We used the Shapiro-Wilk test which is more appropriate in case of a small sample size. Four of the mental effort rating variables (out of 13) did not meet the normality assumption in the no-music group. Similarly, 2 of the mental effort rating variables (out of 13) did not meet the normality assumption in the music group. The data distributions were also checked for the homogeneity of error variances. Results of the Levene's test revealed that for some of the mental effort ratings, the assumption of homogeneity was violated. Therefore, the mental effort scores were transformed by using log-transformation. After transforming the data, Levene's test revealed that the assumption of homogeneity was met for all the variables. We carried out a separate mixed ANOVA analysis to test our first hypothesis by using the transformed mental effort scores. The F-statistics did hardly differ from the F-statistics that were obtained by using the untransformed data. Therefore, we report the results of the Mixed ANOVA analysis that was carried out with the untransformed data here, for the ease of interpretation and for being more straightforward.

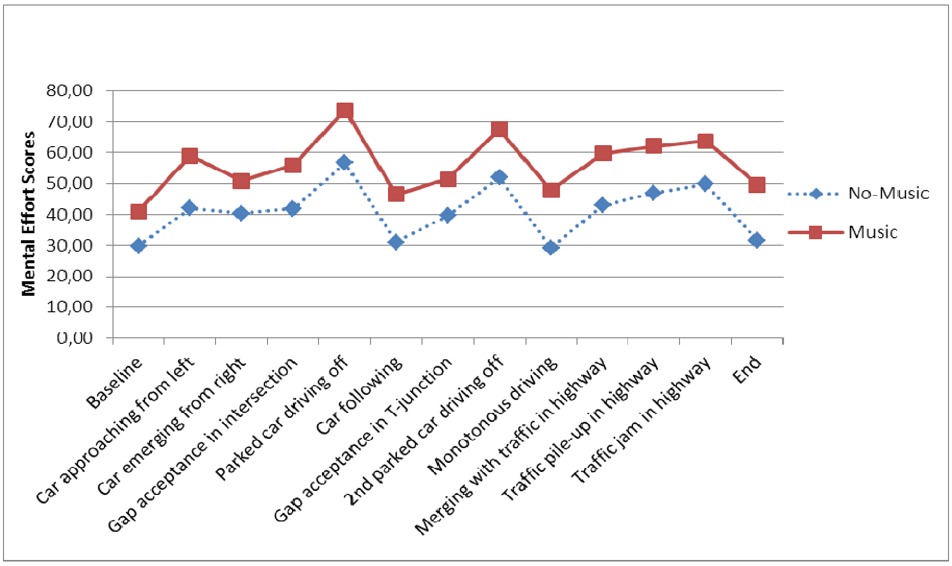

Figure 1. Mental effort scores based on the RSME ratings for the critical and non-critical situations in the music and no-music groups.

3.2. The effect of music on performance in critical driving situations

The driving performance of the music and no-music groups for each critical event was compared by using independent samples t-tests. Two-tailed test of significance was employed to test our hypothesis (equal variances assumed). In line with our hypothesis, the results revealed that the music and no-music groups performed equally well in all but two scenarios. In other words, there was no significant effect of music on driving performance in the majority of the driving situations. The two situations in which the performance of the groups differed were the car-following task and a parked car suddenly driving off from a parking lot.

In the car-following scenario, drivers had to follow a car for approximately six minutes. The lead car was programmed in such a way that it had an irregular pattern of driving, characterized by sudden accelerations and decelerations which lead to a high standard deviation of speed. Therefore, a good performance in the particular task was produced by driving in coherence with the lead car, having little delay in reacting to speed changes of the lead car (De Waard & Brookhuis, 2000), and therefore producing a higher standard deviation of speed (similar to the lead car). The coherence in car-following did not differ (t (58) = 1.02, *ns*.) between the music (*M*= 0.71, *SD*= 0.16) and no-music groups (*M*= 0.66, *SD*= 0.18). However, there was a significant difference between the groups in delay of responding to the accelerations and decelerations of the lead car (t (57) = -2.82, p < .01). The music group had a smaller delay (*M*= 3.44, *SD*= 1.29) than the no-music group (*M*= 4.65, *SD*= 1.92), indicating that the music group responded approximately one second earlier than the no-music group. Importantly, there was a significant difference (t (67) =2.49, p < .05) in the standard deviation of speed between the music (*M*= 6.72, *SD*= 1.48) and no-music groups (*M*= 5.74, *SD*= 1.81), indicating that the music group performed better by adjusting their speed in accordance with the speed changes of the lead car. There was no significant difference between the groups in any of the other performance criteria for the car-following scenario, which were speed, lateral positioning, standard deviation of lateral positioning and time-headway.

In the scenario of a parked car suddenly driving off, we recorded three performance criteria: time-to-contact with the parked car driving off, maximum deceleration during the incident, and maximum brake percentage executed during the incident. Performing well in this scenario meant keeping a higher time-to-contact, along with faster deceleration and braking scores, since all three measures were indicative of the urge to stop in order to avoid a collision with the parked car driving off. We found that the music group had a significantly (t (67) = 2.22, p < .05) higher time-to-contact (*M*= 1.12, *SD*= 0.25) than the no-music group (*M*= 0.97, *SD*= 0.30), indicating that they performed better. However, there was no significant difference between the groups in the other two performance criteria.

3.3 Mental effort as a mediator of the effect of music on driving performance

For the three performance measures that differed between the music and no-music groups (standard deviation of speed in car following, delay in car following, and time-to-contact with the parked car), we ran mediation analysis (see Baron & Kenny, 1986) to see whether mental effort mediated the relationship between music and driving performance. As Figure 2 illustrates, music significantly predicted the dependent variable standard deviation of speed (β= .28, p < .05) as well as the mediator mental effort (β= .41, p < .001). Most importantly, after controlling for the effects of mental effort, the effect of music on the standard deviation of speed was no longer significant (β= -.04, ns) while mental effort predicted the scores in standard deviation of speed (β= .27, p < .05) even after controlling for the effects of music. So, as expected, mental effort mediates the effect of music on performance, suggesting that music influences mental effort, which in turn affects performance. A Sobel test revealed that the mediation effect was marginally significant (Z= 1.79, p= .07).

As shown in Figure 3, music significantly predicted the delay in the car following task (β = -.33, p < .05). Music also significantly predicted the mediator mental effort (β = .40, p < .01). After controlling for the effects of mental effort, the effect of music on the dependent variable delay slightly decreased, but remained significant (β= -.28, $p \leq .05$). Importantly, mental effort did not predict the delay of response after controlling for the effects of music (β= -.11, *ns),* indicating that mental effort did not mediate the effect of music on delay scores in the car following situation.

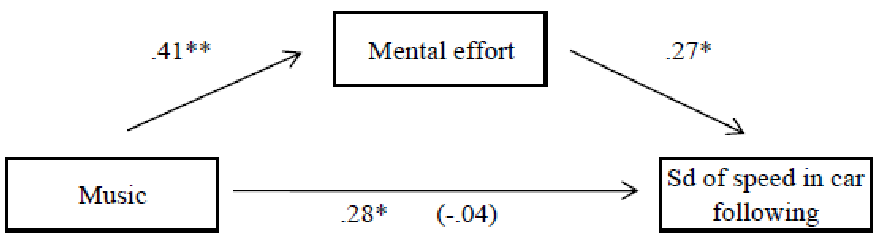

Figure 2. Mediation analyses to test whether mental effort mediates the relationship between music and standard deviation of speed in car following. *Note.* The beta value in parenthesis refers to the effect of the independent variable on the dependent variable after controlling for the effect of the mediating variable.

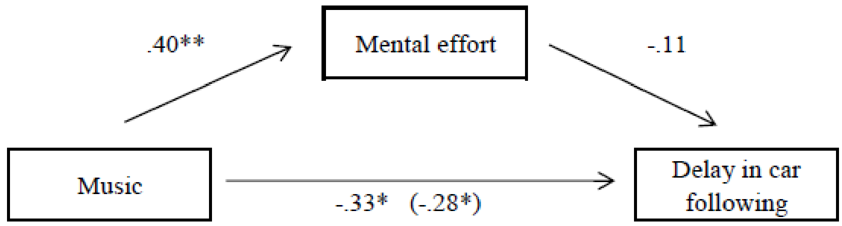

Figure 3. Mediation analyses to test whether mental effort mediates the relationship between music and delay scores in car following. *Note.* The beta value in parenthesis refers to the effect of the independent variable on the dependent variable after controlling for the effect of the mediating variable.

Finally, as illustrated in Figure 4, music significantly predicted time-to-contact with the parked car ($\beta = .24$, $p < .05$) and the mediator mental effort ($\beta = .36$, $p < .01$). After controlling for the effects of mental effort, the effect of music on the dependent variable time-to-contact with the parked car became stronger ($\beta = .33$, $p < .01$), indicating a suppression effect (see MacKinnon, Krull, & Lockwood, 2000) rather than a mediation effect. So, for the time-to-contact with the parked car scenario, the inclusion of mental effort increased rather than decreased the effect of music on performance.

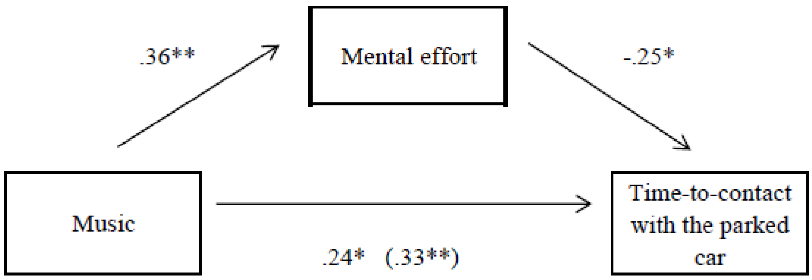

Figure 4. Mediation analyses to test whether mental effort mediates the relationship between music and time-to-contact with the parked car. *Note.* The beta value in parenthesis refers to the effect of the independent variable on the dependent variable after controlling for the effect of the mediating variable.

4. Discussion

The current study aimed to examine the effects of music on mental effort while driving, and on driving performance. We hypothesized that listening to music at a high volume adds to mental load, and therefore increases the mental effort while driving. Second, we hypothesized that despite the increase in mental effort, listening to music does not impair driving performance, and drivers who listened to music will perform as well as the drivers who did not listen to music. In fact, we expected that the music group could even perform better than the no-music group in certain situations, as a result of the regulation of mental effort to meet task demands. Third, we expected that any difference in driving performance of the music and no-music groups would be mediated by mental effort.

Our first hypothesis was confirmed. Drivers who listened to music reported systematically higher levels of mental effort than drivers who did not listen to music. Importantly, the ratings of the drivers who listened to music were higher irrespective of the complexity of the traffic environment (see Figure 1). As expected, the complexity of the traffic environment also appeared as a factor increasing the mental effort while driving. For instance, both in the music and no-music groups, drivers reported a higher mental effort when the context of driving was demanding, such as when confronted with a hazard (e.g. parked car driving off from a parking lot). However, importantly, listening to loud music increased the mental effort even more in such situations. Indeed, the influence of music on mental effort was so robust that we even observed significant effects of music on mental effort during the baseline and end measures, during which the traffic environment was relatively undemanding. Therefore, our findings clearly suggest that loud music increases the mental load while driving, and this applies in both monotonous and complex traffic environments.

Self-reports of drivers have indicated that drivers do not generally perceive music as a distracting auditory stimulus on the road (Dibben & Williamson, 2007; North et al., 2004). However, the current finding on music's influence on mental effort suggests that music can be a distracting stimulus while driving. Given that this is the case, why do drivers hold positive evaluations for listening to music despite the explicit increases in mental effort? Our findings imply that this might be related to the nonnegative experiences with music in terms of driving performance. We found that drivers who listened to music performed at least as well as drivers who did not listen to music in all of the driving situations. This indicates that, generally music did not cause driving performance to deteriorate, providing support for our second hypothesis.

Previously, loud music has been associated with reduced vigilance and impaired peripheral detection in the computer-based tasks (Dalton et. al, 2007; Beh & Hirst, 1999). Our results did not support such a link. This could be due to our experimental method in which we used the driving simulator instead of a computer-based signal detection task. However, we think that this is not the case, because all the hazardous situations in the driving simulator were also depicting signals or unexpected stimuli as they are commonly referred to in the computer-based tasks of vigilance (Turner et al., 1996). Moreover, the simulator allowed us to infer about vigilance and other performance related measures in a more realistic setting, which is close to actual driving. In short, our participants were quite good at the early detection of hazardous situations, such as when a parked car suddenly drove off from a parking lot. Moreover, they were also all good at responding to the traffic coming from the periphery, such as a car violating the give-way rule. So, drivers who listened to music were still vigilant of the stimuli that popped up unexpectedly. Given that the mental effort ratings of the drivers who listened to music were higher than the ones who did not listen to music, our results indicate that drivers regulate their mental effort to maintain their primary task performance (driving) when there is a distracting auditory stimulus in the car. Therefore, our results fully support Hockey's (1997) compensatory control model, and show that regulation of mental effort is a cognitive compensatory strategy that the drivers employ to cope with the task demands.

In addition, we found that the music group performed better than the no-music group in two of the critical situations. The first situation was a hazardous event that required braking hard in order to avoid a crash with a car driving off suddenly from a parking lot. The second situation was a car following task in which participants had to follow a lead car with an irregular pattern of driving. In the parked-car driving off scenario, time-to-contact with the parked car was higher for participants who listened to music. In the car following scenario, participants who listened to music were better in adjusting their driving to the driving pattern of the lead car, and they responded with a smaller delay to the speed changes of the lead car. Indeed, the situations were quite different in nature, as the former represented a sudden hazard requiring faster decision making for response selection, while the latter represents a relatively monotonous situation requiring sustained attention to follow the lead car. Still, both situations required the driver to be alert and focused on the driving task. In addition, in both situations, the mental effort ratings of the participants who listened to music were higher than the ratings of the participants who did not listen to music. Then, can mental effort explain the positive influence of music on performance indicators for the car following and parked car driving off situations?

In line with our third hypothesis, mental effort mediated the effect of music on performance, but this applied only to the standard deviation of speed in the car following task. In terms of the delay in following a lead car, mental effort showed no mediating effects. Car following is a monotonous but effortful task that requires high vigilance (Brookhuis, De Waard, & Mulder, 1994). Our findings suggest that while driving at the same pace with the lead car (standard deviation of speed), regulation of mental effort leads to a better performance for drivers who listened to music. However, in terms of faster reactions to speed changes of the lead car (delay), factors other than mental effort might be mediating the effects of music on performance. One of these factors can be boredom, which is highly relevant to monotonous driving conditions as it represents an underload situation that might cause potential loss of attention (De Waard, 1996). It might be the case that music helped our participants to defeat boredom while busy with a monotonous driving task, leading to faster responses to adjust one's driving to the driving pattern of the lead car. Therefore, future studies should also account for the mediating role of boredom, especially in relation to monotonous driving tasks.

What about the mediating role of mental effort in hazardous situations, such as in the critical event of parked driving off from a parking lot? We found that mental effort did not mediate the effect of music on performance in the parking car driving off scenario. Rather, the effect of music on the performance indicator was stronger when mental effort was controlled for, indicating a suppressor effect. Mental effort ratings were very high in the parking car driving off scenario, for both the music and no music groups. Therefore, it might be the case that when a certain threshold of mental effort is exceeded due to the hazard potential of the situation or due to the music, mental effort no longer mediates the effect of music on performance. In such hazardous situations, other process variables might mediate the effect of music on performance, such as the arousal level which is expected to increase with loud music (North & Hargreaves, 1999). However, in the current study we did not include a continuous measure of arousal like we did for mental effort, so we cannot test this assumption. Future studies should therefore consider checking the mediating roles of both arousal and mental effort to further study the effect of music on driving performance.

Although the results of the current study did not show any impairment in driving performance due to listening to music, it should be noted that it is likely that drivers are not always able to deal with the increased task demands while driving. For example, the lengthened experience of high mental effort might lead to decreases in driving performance, as the driver might feel depleted. In the current study we did not test this assumption because we were mainly interested in whether drivers regulate their invested mental effort to deal with different driving situations. However, it would be interesting to also look at the effects of prolonged driving with music on mental effort and driving performance.

Apart from different driving situations, the characteristics of the music might also influence the effect of music on mental effort and driving performance (Dalton & Behm, 2007). For example, there is evidence that different volume levels affect driving performance differently (Beh & Hirst, 1999). Importantly, listening to music in one's preferred loudness level might be effective for attaining optimal performance levels (Turner Fernandez, & Nelson, 1996). In the current study, we purposefully used only loud music in order to create a demanding listening situation. Future studies could also look at the influence of different sound levels or properties of music (e.g. tempo, complexity, rhythm) on both mental effort and driving performance. Based on our findings we expect that irrespective of the property being manipulated, music would increase mental effort if it is demanding to listen to.

We employed a young sample in our study. It is possible that young drivers can handle more demanding types of music better than older drivers. Furthermore, young drivers are better at dealing with complex traffic situations as compared to older drivers (Cantin, Lavalliere, Simoneau, & Teasdale, 2009). Therefore, the demands induced by music may be even stronger for older participants. Future studies should explore whether our results can be replicated in different samples, including samples of older drivers.

5. Conclusions

The majority of drivers listen to music or the radio while driving (Dibben & Williamson, 2007). Therefore, it is important to track the influence of music on driving performance. The current research makes some important contributions to the existing literature on music and driving. First, based on our finding related to the increases in mental effort while listening to music, we objectively showed that music can be a demanding and distracting stimulus on the road. Yet, drivers seem to be able to keep a desired performance level with the presence of music. Importantly, we clearly showed that drivers make use of cognitive compensatory strategies to deal with the distracting effects of music, and regulation of mental effort seems to be an effective strategy to cope with the additional load created by music. Future studies should test the mediating roles of other process variables such as arousal or boredom, to provide further knowledge on how music influences driving performance.

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Appendix

Description of Critical Driving Situations and Relevant Performance Indicators

1. Car emerging from the right: This scenario mirrored a hazardous driving incident in which another car unexpectedly emerged from a merging road to the right of the driver. The following performance indicators were used:

1.1. Maximum deceleration: The greatest deceleration value in m/s. Higher values of maximum deceleration indicate harder brake responses meaning that the driver started to brake at a shorter distance from the hazardous event.

1.2. Minimum velocity: The smallest speed in m/s.

1.3. Maximum brake: The brake pedal position as a percentage from 0 to 100.

2. Car approaching from the left: This scenario mirrored a hazardous driving incident in which another car approached from a merging road to the left of the driver. Although the driver had the right to pass through the intersection first, the other car did not stop, violating the give way rule. The performance indicators were the same as the car emerging from the right scenario.

3. Gap acceptance at an intersection: This scenario depicted a situation in which the participant had to cross an intersection where there were cars coming from left and right. The gap between the oncoming cars increases at a certain frequency. We were interested in the gap that the driver chooses to cross the intersection. The performance indicators for the situation were:

3.1. Accepted gaptime: A measure in seconds, indicating the time between the movements of two oncoming cars. The higher the gaptime, the longer the driver waited to cross the intersection.

3.2. Distance to cars that are approaching: It correlates with accepted gaptime, and indicates of the distance between the two oncoming cars.

4. Car driving off from a parking lot: In this critical situation, a parked car unexpectedly drove off from a parking lot, and cut into the driver's way when the driver was passing. The driver was expected to brake immediately in order to avoid a collision. The following performance indicators were recorded:

4.1. Maximum deceleration (see 1.1)

4.2. Maximum brake (see 1.3)

4.3. Time to contact: The time in seconds that would lead to a collision to the first object in the same lane as the participant, which is the parked car driving off in this scenario.

5. Car following task: In this scenario, the task was to follow a lead car at a constant but safe distance. The speed of the lead car was varied purposely in an irregular way. The following performance indicators were used:

5.1. Speed: Mean speed while following the lead car.

5.2. Standard deviation of speed: A measure aimed at tracking the variations in speed. As the lead car had a high standard deviation of speed due to sudden accelerations and decelerations, a higher score in this measure indicates that the driver was able to adjust his/her driving to the driving pattern of the lead car.

5.3. Lateral positioning: The position of the car in one's own lane. A negative lateral position means that the car was to the right of the centerline, while a positive lateral position indicates that the car was to the left of the centerline. A lateral position of 0 suggests that the car was exactly in the middle of the driving lane.

5.4. Standard deviation of lateral positioning: An indicator of swerving on the road and car-control. If high, it indicates that the driver had failed to control the car smoothly.

5.5. Mean minimum time headway: An indication of the time needed for the following car to reach the location of the lead car.

5.6. Absolute minimum time-headway: The smallest time-headway to the lead car.

5.7. Coherence: An indication of accuracy of following a lead car.

5.8. Delay: An indication of the delay of responding to the speed changes of the lead car.

6. Gap acceptance at a T-junction: The driver had to turn left in a T-junction in which there was oncoming traffic. The gap between the oncoming cars increased with a certain frequency. We were interested in the gap at which the driver chose to turn left. The performance indicators for the situation were the same as for the gap acceptance at an intersection scenario.

7. Monotonous driving: In this scenario, the driver drove on an empty intercity road. Therefore, the situation represented a monotonous driving condition where there was a lack of external stimuli. The performance indicators for the monotonous driving were mean speed, standard deviation of speed, mean lateral positioning and standard deviation of lateral positioning (see 5.1, 5.2, 5.3 and 5.4)

8. Merging with the traffic on a highway: In this scenario, the driver had to enter a highway where there was oncoming traffic coming from left. The driver had to watch out for other cars that were approaching at a high speed, and decide on a safe time to merge with the traffic. The performance indicators representing the scenario were:

8.1. The velocity (in m/s) while merging with the traffic in highway.
8.2. Time- headway with the lead car while merging.
8.3. Time-to-contact with the lead car while merging.
8.4. Time- headway with the rear car while merging.
8.5. Time-to-contact with the rear car while merging.

9. Traffic pile-up on the highway: While driving on a highway, the driver saw other cars behind, approaching at high speeds. The other cars then started to overtake the driver, and built a heavy traffic in front of the driver. The driver needed to be alert, and to watch out for all the traffic in order to avoid a crash with the cars behind and in front. The performance indicators for the scenario were:

9.1. Mean minimum time-headway: See 5.5.
9.2. Absolute minimum time-headway: See 5.6.

10. Traffic jam: In this scenario, the driver ended up in a traffic jam, and needed to control the simulated car very smoothly to avoid a crash with other cars. The performance indicators were:

10.1. Mean time-to-contact: Mean of all time-to-contact scores.
10.2. Absolute minimum time-to-contact: The smallest time-to-contact score

Chapter 3

Blocking-out Auditory Distracters while Driving: A Cognitive Strategy to Reduce Task-Demands on the Road

This chapter is based on Ünal, A.B., Platteel, S., Steg, L., Epstude, K. (2013). Blocking-out auditory distracters while driving: A cognitive strategy to reduce task-demands on the road. *Accident Analysis and Prevention*, *50*, 934-942.

Abstract

The current research examined how drivers handle task-demands induced by listening to the radio while driving. In particular, we explored the traces of a possible cognitive strategy that might be used by drivers to cope with task demands, namely blocking-out auditory distracters. In Study 1 (N= 15), participants listened to a radio-broadcast while watching traffic videos on a screen. Based on a recall task asking about what they had listened to, we created baseline scores reflecting the general levels of blocking-out of radio content when there was no concurrent driving task accompanying the radio-listening. In Study 2 (N= 46), participants were asked to complete two drives in the simulator: one drive in high-complexity traffic and another in low-complexity traffic. About half of the participants listened to a radio-broadcast while driving, and the other half drove in silence. The radio-listeners were given the same recall task that we had used in Study 1. The results revealed that the participants who drove while listening to the radio (Study 2) recalled less material from the radio-broadcast as compared to the participants who did not drive (Study 1). In addition, the participants who drove while listening to the radio recalled less talk-radio excerpts when driving in high-complexity traffic than when driving in low-complexity traffic. Importantly, listening to the radio did not impair driving performance. Together, these findings indicate that blocking-out radio content might indeed be a strategy used by drivers to maintain their driving performance.

1. Introduction

Drivers may engage in various driving-unrelated tasks on the road. These behaviors, which suggest an inclination of multitasking, may vary from eating or drinking to smoking and tuning the radio at the same time (Stutts et al., 2003, Lansdown, 2012). The influence of multitasking on driving behavior has received considerable attention in research, thereby differentiating the secondary tasks based on visual, manual, cognitive or auditory sources of distraction (Ranney, Garrot, & Goodman, 2000). Previous studies especially demonstrated that the visual and manual distracters impose serious demands on drivers and inhibit driving performance; as such these distracters rely on the same mental resources as driving (Horberry, Anderson, Regan, Triggs, & Brown, 2006; Harbluk, Noy, Trbovich, & Eizenman, 2007). With regard to auditory distracters, however, the results were rather mixed. Some studies showed that auditory distraction has no detrimental effects on driving performance and can be handled quite well by drivers (Wester, Böcker, Volkerts, Verster, & Kenemans, 2008; Cnossen, Meijman, & Rothengatter, 2004), while some other studies showed that auditory distracters might actually impair task performance in a similar way that visual and manual distracters do (Chaparro, Wood, & Carberry, 2005; Gherri & Eimer, 2010). In the current research, we propose that auditory distracters impose additional demands on the driving task as well, and that drivers are able to handle these demands and still attain a desirable performance level. In addition, we explore the processes that might explain how driving performance is maintained in the prevalence of auditory distracters. More specifically, we suggest that blocking-out auditory distracters by paying less attention to the audio-sources might be a common strategy employed by drivers to handle increased task demands.

Previous studies on drivers' engagement with other tasks on the road revealed that multitasking is likely to impair primary task performance (McEvoy, Stevenson, & Woodward, 2007; Drews, Pasupathi, & Strayer, 2008; Strayer & Drews, 2003; Consiglio, Driscoll, Witte, & Berg, 2003). For instance, several studies documented that the use of a mobile phone or talking to passengers was related to increased crash likelihood and decreased vigilance (Collet, Clarion, Morel, Chapon, & Petit, 2009; McEvoy et al., 2007; Strayer & Johnston, 2001, McKnight & McKnight, 1993), suggesting that keeping up with a conversation while driving might distract the driver and pose danger on the road. Other types of distracters or secondary tasks that do not involve a conversation were also related to flaws in driving performance. As an example, performing a secondary cognitive task impaired the visual scanning abilities of drivers, leading to violations of give-way rules and disregarding the passengers (Anttila & Luoma, 2005). Similar results were obtained for other distracters, including operating the audio-entertainment devices, reading directions, and eating or drinking (Young, Mahfoud, Walker, Jenkins, & Stanton, 2008; Jenness, Lattanzio, O'Toole, & Taylor, 2002).

One of the most common in-vehicle distracter is listening to music or the radio (Dibben & Williamson, 2007). Then, how would listening to music or the radio influence driving performance? Previous studies suggest that listening to music or the radio either had no-effects or positive effects on driving performance (Ünal, Steg & Epstude, 2012; Hatfield & Chamberlain, 2008; Strayer & Johnston, 2001; Wiesenthal, Hennessy, & Totten, 2000; Turner, Fernandez & Nelson, 1996; Fontaine & Schwalm, 1979). For instance, in a simulated driving context, listening to music and talk-radio fragments had no influence on lateral positioning, speed and reactions to hazardous incidents (Hatfield & Chamberlain, 2008). Similarly, listening to the radio was found to have no influence on drivers' performance in a tracking task (Strayer & Johnston, 2001), suggesting that radio-listening can be handled well while driving.

Some other studies, however, indicated that drivers cannot handle music or the radio while driving (Jäncke, Musial, Vogt, & Kalveram, 1994; Brodsky, 2002; Dalton, Behm, & Kibele, 2007). As an example, a driving simulator study revealed that participants increased their speed and engaged in more red-light violations while driving along with high tempo music on the background (Brodsky, 2002). It was concluded that depending on some structural properties (e.g. high-tempo), music can be a cognitive distracter affecting driving performance negatively. Supporting this argument, North and Hargreaves (1999) reported increases in lap times in the simulator when the listening situation was demanding (i.e., high tempo and high volume music) rather than not demanding (i.e., low tempo and low volume music). Importantly, the authors detected that lap time was the longest when the demands were increased further by coupling high tempo-high volume music with a concurrent task of backward counting. Together, the findings of North and Hargreaves (1999) indicate that the influence of in-vehicle distracters on driving performance rely on the demands induced by those distracters. Then, are we likely to end up with a lowered driving performance when listening to auditory stimuli in demanding situations?

In a recent investigation of the influence of a demanding type of listening situation on driving performance, Ünal and colleagues (2012) showed that listening to loud music significantly increases self-reported mental effort while driving, irrespective of the specific driving conditions and tasks. Interestingly, it was also found that drivers were quite capable of dealing with the demands induced by music, and listening to music did not negatively affect driving performance. In fact, the driving performance of the group listening to music was even better than the driving performance of a no-music group for some driving tasks such as car following. The findings indicated that even if an auditory distracter is very demanding (as observed by consistent increases in mental effort), this does not necessarily translate into impaired driving performance. So, how do drivers preserve their primary task performance in such situations of high demand?

As also shown by North and Hargreaves (1999), drivers are good at adjusting their driving patterns to meet task demands, by decreasing their speed or increasing the distance with the lead car (Young & Regan, 2007; Törnros & Bolling, 2006; Kubose et al., 2006; Lansdown, Brook-Carter, & Kersloot, 2004; Brookhuis, De Vries, & De Waard, 1991). However, drivers may also rely on other kinds of compensation strategies that do not require them to adjust their driving pattern. For instance, instead of regulating their driving behavior, drivers might regulate their allocation of cognitive resources to secondary tasks (Kahneman, 1973; Hockey, 1997). As a result, they might either completely refrain from the secondary task, or start paying attention to it less thoroughly so as to preserve the primary task performance at a desired level (Hockey, 1997). Some studies provide initial support for this strategy of investing less effort in the secondary task. For instance, during a conversation with a passenger or on a mobile phone, drivers decreased their speech production rates or speech complexities when the demands of the traffic increased (Maciej, Nitsch, & Vollrath, 2011; Drews et al., 2008; Crundall, Bains, Chapman, & Underwood, 2005). Similarly, drivers were found to ignore a driving unrelated secondary task (i.e., auditory working memory task) more than driving related secondary tasks (i.e., using route finding tools; Cnossen et al., 2004). As such, they prioritized both the driving task and the tasks that are related to driving. In general, these findings suggest that secondary tasks may receive less attention from drivers if they pose threat to driving safety, or if they are irrelevant to the driving task. Can we observe a similar trend while listening to music or the radio in a demanding traffic environment? Would drivers avoid paying attention to the radio in such situations in order to maintain their desired level of driving performance? Or would they still be engaged with the radio and cope with multiple task demands?

1.1. Current Research

In the current research, we propose that drivers who listen to the radio would be able to preserve their driving performance despite the demands induced by the radio. We believe that the maintained driving performance of the radio-listeners will be related to paying less attention to the secondary task of listening to the radio, in order to regulate attentional resources so as to concentrate better on the primary task. We refer to this inclination of paying less attention (either consciously or not) to the secondary task of radio-listening as blocking out the radio content. We expect that as a result of blocking-out the content, drivers would recall less material from a radio-broadcast, suggesting a lower secondary task performance while driving.

It may be that blocking out may also take place in a regular context of listening to the radio, in which listening to the radio is not accompanied by a challenging task or is hardly demanding (e.g. at home). Therefore, in order to be able to draw conclusions on whether the radio-content is indeed blocked-out more when one has to carry out a demanding task (i.e., driving), we first ran a baseline experiment (Study 1). The baseline experiment provided us with a measure that can serve as a reference index showing the regular patterns of blocking-out during radio-listening.

In addition, the demands of a driving task are not stable either, and depend on the traffic environment such as the level of traffic density and the prevalence of conflict situations that one has to negotiate (Stinchcombe & Gagnon, 2010; Horberry et al., 2005; Cnossen et al., 2004; Baldwin & Coyne, 2003; De Waard, 1996). A driver might still have enough cognitive capacity to carry out multiple tasks on the road if the traffic demands are not exceeding his or her potential. In our case for instance, a driver may still pay some attention to a program on the radio when the traffic is calm. When the traffic complexity is higher, however, we expected that drivers would allocate more cognitive resources to the driving task, and would not pay careful attention to a secondary task that is irrelevant for driving safety, like listening to the radio. So, we expected that the inclination to block-out the radio content would increase even further when the traffic complexity is higher. We tested these assumptions in Study 2.

More specifically, in Study 2, we first checked whether drivers who listened to the radio were able to preserve their driving performance, and perform as well as the drivers who drove in silence. In explaining the mechanism behind the sustained driving performance of radio-listeners, we formulated two hypotheses. First, we hypothesized that individuals who listened to the radio while performing a concurrent driving task would remember less from a radio broadcast as compared to individuals who listened to the radio without performing a concurrent driving task. Second, we hypothesized that drivers who listened to the radio would remember less from a radio broadcast during a drive in high-complexity traffic, while they would remember more from a radio broadcast during a drive in low-complexity traffic. In other words, we expected that drivers would prioritize the driving task, and would lower their engagement with the radio when the traffic is more demanding.

2. Study 1

Study 1 aimed to find out how much of radio-content is being blocked-out and remained unattended in a regular context of listening. This way, we created a reference index to be used in Study 2, so that we would be able to compare whether the tendency to block-out the radio content differs when one is busy with driving rather than solely listening to the radio. We used the same radio-content and a similar procedure of radio-listening in both studies, as explained in Section 2.1.3.

2.1. Method

2.1.1. Participants

Fifteen students (11 females and 4 males) of the Psychology Department of the University of Groningen participated in the first study. The participants had a mean age of 21.20 (*SD*= 8.20). None of them reported having any hearing deficiencies.

2.1.2. Research design and procedure

Upon arrival, participants were instructed that they would watch a series of traffic videos during the course of the experiment. The use of the videos was both a cover to mask the real purpose of the study, as well as a visual stimulation to prevent participants from daydreaming while listening to the radio-program. The video-footage reflecting a Dutch traffic environment was from a Dutch TV program called the De Bijrijder ('Co-driver', TV Noord, 2011). The videos were all captured inside of a vehicle from a co-driver's perspective, depicting regular city and intercity driving situations in the Netherlands. The videos were projected on a big screen, and were played in mute to make sure that the sounds in the original video recordings would not interfere with the radio broadcast.

We told the participants that we were trying to create a situation similar to real-life driving, and therefore a radio-broadcast consisting of talk-radio excerpts, commercials and music excerpts would accompany the videos. At this point, we asked the participants to fill in a short scale and indicate their top-three music genre, so that we were able to play the music excerpts from their favorite genres during the experiment (see 2.1.3) as to ensure that any failures in recall of the music excerpts would not be attributed to unfamiliarity with the music or disliking the music.

In real-life, people's attention to radio programs might differ during the course of a radio program. Listeners might block-out some of the radio-content while they might pay careful attention to some other content. We wanted our experiment to reflect real-life experiences as much as possible, and therefore did not communicate the radio-content recall as an explicit task. Instead, we instructed the participants that they could be asked some questions about the radio-program afterwards. This methodology ensured that participants would be aware of the possibility of a recall task after the experiment, while they would still be free to decide on the extent to which they pay attention to the content.

The volume of the radio was moderate with a sound level of approximately 75dB throughout the experiment. After watching the video clips and listening to the radio program, participants were given the questionnaires and check-lists for the recall task (see Section 2.1.4). At the end of the recall task, participants rated whether they actively tried to keep the radio-content in mind, on a 6 point Likert-type scale (1= not at all, 6= all the time). We found that participants did not try to actively encode the radio content into memory (M= 2.79, SD= 1.42). This suggests that we were successful in creating a radio-listening situation that is close to real-life experiences, and that the results of this study can be used as a reference point for general indices of blocking-out radio-content.

2.1.3. Radio-Broadcast

We created seven radio-broadcasts that were 40 min long each, and consisting of talk-radio excerpts (i.e., a DJ interviewing guests), commercials and music excerpts. The commercials and talk-radio excerpts were all the same in the different radio-programs. The programs differed only in terms of the music genre that was played, so that every participant listened to his or her preferred type of music during the experiment.

The radio programs included seven talk-radio excerpts recorded from Dutch radio-stations in the months preceding the study that covered a broad range of topics, from politics to world cuisine, and lasted about 16 minutes. Besides, a total of 41 commercials were randomly recorded from the Dutch radio stations as well. The total length of the commercials was 14 minutes.

In choosing the music genres that were listened to in different radio-programs, we used the classification of Rentfrow and Gosling (2003). The genres we selected were rock, electronic, funk/soul, pop, jazz/blues and chill/dance. In addition, we created a radio-program that played Dutch music only. We used music websites (i.e., Last FM) and Top-100 charts on the web to select artists and bands that are representative and prototypical of each genre, and created short music excerpts from each song (by selecting a fragment of the song that is widely known such as the chorus) that lasted between 29 to 35 seconds each. We selected a total of 30 music excerpts for each genre, which lasted about 15 minutes in total. At the end of the experiment, participants were asked to indicate how many songs they could sing along on a 7-point Likert type scale (1= none, 7= all; *M*=5.87, *SD*=1.06), which revealed a high familiarity with the music broadcasted.

In Study 2, participants would be asked to complete two simulated drives (see section 3.1.2), so the radio-broadcast would be presented in two parts. We broadcasted the radio-content in two parts in Study 1 as well, since we wanted both studies to be structurally similar in procedures related to radio-listening. Participants listened to the talk-radio excerpts, commercials and music excerpts as blocks in each part. So, when one type of audio stimulus has ended, the other was broadcasted. The order within music excerpts, commercials and talk-radio excerpts in each block was the same across participants. The presentation order of the first part and the second part of the radio broadcast was kept constant across participants too. However, we counterbalanced the presentation order of music and commercials/talk-radio in each block. Therefore, in half of the cases, the radio-program started with music excerpts, and in the other half it started with commercials/talk-radio excerpts.

2.1.4. Dependent Variable: Percentage of Recalled Radio Content

We tracked how much of the talk-radio excerpts, commercials and music excerpts had been recalled. For the talk-radio excerpts, participants were asked to answer some questions tapping on the topics discussed during the interviews. The questions were constructed in such a way that they always had only one correct answer, with no room for ambiguity. For each block of talk-radio excerpts either in the first or second part of the radio program, we counted the number of correct answers. Then we converted the total number of correct answers into percentage scores, reflecting the amount of talk-radio excerpts that were recalled in the first and second part of the radio program.

For the music excerpts and commercials, participants were given check-lists with brand names and names of artists or songs. For commercials, the list consisted of 99 brand names in alphabetical order, 41 of which were the brands that were broadcasted during the radio program. For recall of the music, the lists consisted of names of 90 artists or songs in alphabetical order, 30 of which were the names of the artists or songs that they had been listening to during the radio program. Participants were instructed to circle the brand names or names of the artists or songs that they recalled from the radio program on the lists. We counted the number of correct items, and again computed percentage scores indicating the amount of commercials and music excerpts that were recalled in the first and second part of the radio program. For each type of audio stimuli, we also checked whether time lag had any influence on recall of the radio content, such as recalling less material from the first part as compared to the second part which was heard just before the recall task.

2.2. Results

We found that participants recalled the topic of more than half of the talk-radio excerpts they had listened to in the first and second part of the radio-program; M= 55.91 (SD= 16.78) and M= 60.59 (SD= 16.75) respectively. A repeated measures analysis revealed that the percentage of recalled talk-radio excerpts in the first part was not significantly different from the percentage of recalled talk-radio excerpts in the second part, indicating that time lag did not influence the recall performance, $F(1,14) = 1.15$, $p > .05$ $\eta_p^2 = 0.08$. Participants recalled less than half of the commercials that they had listened to in the first and second part of the radio-program; M = 38.25 (SD= 18.17) and M = 41.81 (SD= 16.94) respectively. A repeated measures analysis revealed that, again time lag did not affect the recall performance, $F < 1$, *ns*., $\eta_p^2 = 0.05$. Finally, we found that participants recalled about half of the music excerpts they had listened to in the first and second part of the radio-program; M = 54.22 (SD= 23.21) and *M* = 47.56 (*SD*= 17.43) respectively. A third repeated measures analysis revealed that the percentage of music excerpts recalled from the first part was not significantly different from the percentage of music excerpts recalled from the second part, $F(1,14) = 1.72$, $p > .05$, $\eta_p^2 = 0.11$.

As time lag had no influence on the recall of the radio content, we created our reference index by averaging the scores we had calculated for the first and second parts of the different radio contents. So, we had single percentage scores depicting the recall performance for each type of audio stimuli (talk-radio excerpts, commercials and music excerpts), instead of having separate percentage scores for the first and second parts.

3. Study 2

In Study 2, we examined the extent to which drivers pay attention to the radio content while driving, and especially in traffic environments with high or low complexity. To test our first hypothesis, we examined how much of the radio content had been recalled when the radio-listening was accompanied by a driving task (i.e., Study 2), as compared to when it was not accompanied by a driving task (i.e., Study 1). To test our second hypothesis, we examined how much of the radio content has been recalled by drivers from a drive that took place in high-complexity traffic as compared to a drive that took place in low-complexity traffic. Prior to testing our hypotheses, we wanted to confirm whether our initial idea of drivers' prioritizing the driving task while listening to the radio would hold true. So, we first checked whether radio-listeners performed as well as the drivers who drove in silence in Study 2.

3.1. Method

3.1.1. Participants

Fifty students of the Psychology Department at the University of Groningen participated in the study. Four of the students were excluded from data analysis due to either simulation sickness or not being native Dutch-speakers. The remaining 46 participants (25 female) had an age range of 18 to 29, with a mean age of 21.83 (*SD*=

2.44). Participants' mean mileage covered in the year preceding the study was 4308 km (*SD*= 6125). None of the participants reported having hearing deficiencies.

3.1.2. Research Design and Procedure

The study employed a 2 (auditory distraction: listening to the radio or no-radio) X 2 (traffic complexity: low and high) mixed subjects design with repeated measures on the second factor. Participants were randomly assigned to the radio or no-radio conditions[3].

We instructed the radio-group participants to drive in the simulator with the radio playing on the background. As in Study 1, we instructed them that they might be asked to answer some questions about the radio-content afterwards. Then, we asked them to indicate their top-three genres of music in order to play the preferred genre of music for each participant.

Prior to the simulated drive, all the participants completed a training session in the simulator. The experimental simulated drive composed of two parts. One part involved driving in a low complexity traffic setting and the other part involved driving in a high-complexity traffic setting. Complexity of the driving environment was manipulated by the traffic density of the oncoming traffic and the number of critical incidents occurring on the road (see 3.1.5). Participants listened to the same radio-broadcast that we used in Study 1 and with the same amplitude of 75dBA. Along with the counterbalancing procedure regarding the presentation order of the radio-content (as explained in 2.1.3), we also counterbalanced the order of starting to drive in low or high-complexity traffic settings. The greater number of counterbalancing in the radio group created the necessity to employ a larger sample for the radio group than for the no-radio group. Therefore the sample size of the no-radio group was

[3] As we randomly assigned the participants to radio and no-radio groups, we did not have control over the gender or age distribution in the samples of the groups. Investigation of the gender distribution of the two samples revealed that the radio group included slightly more females (62.5%), while the no-radio group included more males (64.3%). We did not find any significant differences in age; $F(1,44)= 2.37$, ns), and annual mileage reported for the year preceding the study across the groups ($F<1$, ns.), meaning that the driving experience of the radio and no-radio groups were similar.

approximately half of the sample size of the radio group (n= 14 and n= 32, respectively). As sample size differs across both groups, we assumed that the variance within groups is unequal in the relevant tests.

All participants drove in both the high and low-complexity traffic. At the end of each ride, participants evaluated the completed ride in terms of complexity. After the simulated drives, the radio group participants were immediately given the recall task in which they answered questions asking about what they have listened to while driving. They also indicated to what extent they were able to sing along with the music excerpts, which revealed a moderate familiarity with the music broadcasted (M=5.09, SD=1.51).[4] All the participants also filled in some additional questionnaires asking about demographic and driving related characteristics.

3.1.3. Manipulation check

In order to carry out manipulation checks for traffic complexity, we developed a short scale to be filled in after each drive in the simulator. The scale consisted of 14 adjectives describing the complexity of a driving situation (e.g. demanding, monotonous, risky, tiring, boring). Participants indicated to what extend the adjectives reflected the traffic environment that they have just been to by using a Likert type scale from 1 (strongly disagree) to 7 (strongly agree). A reliability analysis showed that the scale had a high internal consistency (Cronbach's alpha = .86). Therefore, mean scores were computed for participants' evaluations of the low and high complexity traffic environments, respectively, with a higher mean reflecting a higher perceived complexity of the traffic environment.

3.1.4. Dependent Variable: Percentage of Recalled Radio Content

We calculated the percentage of recalled radio content following the same procedure as in Study 1 (see 2.1.4).

[4] The comparison of the music familiarity ratings in Study 1 and Study 2 indicated a marginally significant difference between the two samples $F(1,46)= 3.17$; $p=.08$, meaning that familiarity with the music excerpts was higher in Study 1 than in Study 2.

3.1.5. Dependent Measures: Driving Parameters

We used the driving simulator of University of Groningen (STSoftware) which consists of a fixed-base driving console surrounded by three LCD screens, providing a 180 degrees field of view of the driving environment. The simulator had all the usual equipment for car-control, and responses were recorded in the database at a sample rate of 10Hz.

For the current study we designed two different simulated worlds, being either high or low in traffic complexity. The worlds included the same driving route that consisted of urban and rural areas. The urban and rural areas both consisted of a single carriageway with two lanes, with a lane width of 3 meters. The speed limit was 50km/h in urban areas, and 80km/h in rural areas. It took the participants 15-20 minutes to complete each part, depending on their speed. In high complexity traffic, we had the following critical incidents: 1. car emerging from the right (5 times); 2. car approaching from left and violating the give-way rule (3 times); 3. gap acceptance at an intersection; 4. gap acceptance at a T-junction; 5. parked car driving off a parking lot (2 times). In low-complexity traffic, we only had the incidents of gap acceptance at an intersection and parked car driving off a parking lot. By means of critical events occurring in high and low complexity traffic, we were able to measure a variety of performance indicators, such as time-to-contact or brake-response to hazards. Appendix provides a detailed description of all the critical events and performance indicators included in our study.

3.2. Results

3.2.1. Manipulation check for traffic complexity

Results of a mixed-model ANOVA, with low and high complexity traffic as the within-subjects factor, and with listening to the radio as the between-groups factor revealed that there was a main effect of traffic complexity on participants' ratings of low and high-complexity traffic situations, F (1,44)= 85.65, p< .001, η_p^2= 0.66. As expected participants rated the low complexity drive (M= 3.11, SD= 0.75) as lower in traffic complexity than the high complexity drive (M= 4.46, SD= 0.87). There was no main effect of radio-listening on ratings of traffic complexity, F<1, *ns*., η_p^2= .001 . The interaction of listening to the radio and driving in low and high complexity traffic was not significant either, F<1, *ns*., η_p^2= .006, Therefore, regardless of the presence of the radio on the background, participants indeed evaluated the high complexity traffic as more complex than the low complexity traffic, suggesting that our manipulation of traffic complexity was successful.

3.2.2. The influence of listening to the radio on driving performance

In order to check our initial expectation regarding no impairment in driving performance while listening to the radio, we used multivariate analysis of variance (MANOVA) and compared the driving performance of the radio and no-radio groups in low and high complexity traffic settings. As described earlier in 3.1.5, we had a number of critical incidents and several driving performance indicators for each critical incident (see Appendix). In multivariate statistics, it is advised to include no more than 10 dependent variables in MANOVA if the sample size is not large (Stevens, 1980). Due to the small sample size, we were not able to run an overall MANOVA with all the dependent variables. Instead we ran MANOVAs for each critical incident and their subsequent indicators.

The results of the MANOVA analyses revealed no influence of radio-listening on driving performance during critical incidents in high-complexity and low complexity traffic (F values ranging from 0.32 to 2.14, all being non-significant at p< .05; η_p^2s ranging from 0.02 to 0.17). So, as expected, the results suggested that the driving performance of the radio group was not different than the driving performance of the no-radio group.

3.2.3. Paying attention to the radio content while driving versus not driving

In order to check whether people recall less from a radio broadcast when listening to the radio was accompanied by driving (Study 2) versus not (Study 1), a one-way ANOVA was run. In other words, we compared the percentages of recalled radio content we obtained in Study 2 with the reference index created in Study 1 (see 2.2). Prior to the ANOVA, we first checked the sample characteristics of Study 1 and Study 2. The mean age of the sample we employed in Study 1 was not significantly different from the mean age of the sample we employed in Study 2, $F<1$, *ns*. In addition, in both of the studies, the percentage of females was higher than the percentage of males (73.3% in Study 1 and 62.5% in Study 2), meaning that the sample characteristics of the studies were similar, and not likely to confound the findings.

As seen in Table 1, there were significant differences between the two samples in terms of how much has been recalled after the radio-broadcast. The percentage of recalled radio material was consistently lower when listening to the radio was accompanied by driving (Study 2) than when it was not accompanied by driving (Study 1). Importantly, this applied to all types of radio-content. In general, the findings on lower percentages of recall in Study 2 (driving and listening to the radio) support our first hypothesis that participants would prioritize the primary task of driving and pay less attention to the secondary task of listening to the radio.

3.2.4. Paying attention to the radio content while driving in low and high-complexity traffic settings

In order to check whether participants who had the driving task paid attention to the radio-content differently based on the level of traffic complexity, we ran mixed-model ANOVAs, with the percentage of recall of the radio-content in high and low complexity driving as the within groups factor, and with the order of starting the simulated driving session in a high complexity or low complexity traffic as the between groups factor[5].

[5] When gender was used as a between-groups factor in the mixed-model ANOVAs, it revealed no effects on the percentage of radio-content recalled (F values ranging from 0.22 to 0.64, all being non-significant at $p<.05$).

The results of the first mixed-model ANOVA revealed a main effect of traffic complexity on the percentage of talk-radio excerpts recalled, $F(1,30)= 6.77$, $p < .05$, $\eta_p^2= 0.18$. In line with our second hypothesis, the percentage of talk-radio excerpts recalled was lower when participants had been driving in the high complexity traffic setting (*M*= 34.04, *SD*= 14.03) as compared to the low complexity traffic setting (*M*= 43.59, *SD*= 21.29).

Table 1. Comparing the Radio (No-Driving) and Radio and Driving Groups Based on the Percentage of Radio Content Recalled

	df	Radio and Driving (n= 32) Mean	Radio (No-Driving) (n=15) Mean	F	p	η_p^2
1. Recall % in high complexity situation versus no driving						
Talk-radio		34.04	58.25	29.79	.000	.40
Commercials		29.01	40.03	5.94	.019	.12
Music		36.14	50.89	5.68	.021	.11
Between Groups	1					
2. Recall % in low complexity situation versus no driving						
Talk-radio		43.59	58.25	5.81	.020	.11
Commercials		26.76	40.03	6.94	.012	.13
Music		32.11	50.89	9.90	.003	.18
Within Groups	45					

Note. Within the radio and no-driving condition (Study1), we had single scores for the recall of talk-radio excerpts, commercials and music excerpts. So, the recall percentages are the same in each set, reflecting the baseline recall performance when there was no driving task.

There was no main effect of order of starting to drive in high complexity or low complexity traffic on percentage of recall (F (1,30) = 1.60, p= .22, η_p^2 = 0.05). Importantly, the interaction of traffic complexity and order of starting to drive in high or low complexity traffic did not have a significant effect on the percentage of talk-radio excerpts recalled either, $F(1,30)= 1.99$, $p= .17$, $\eta_p^2= 0.06$. So, the higher percentage of recall during the low complexity traffic was not due to time lag (see Figure 1).

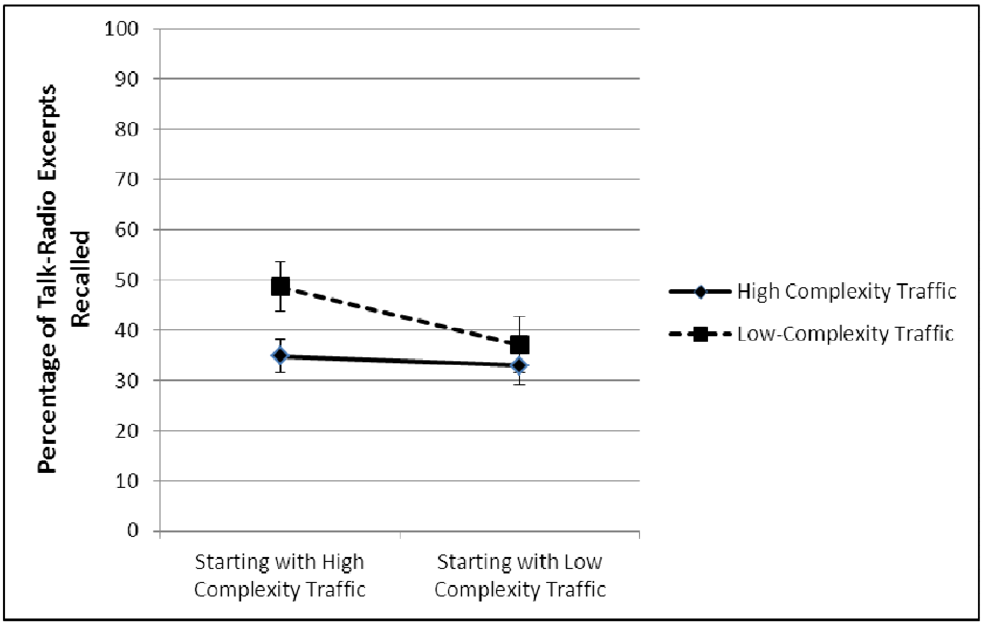

Figure 1. Percentage of talk-radio excerpts recalled during driving in high-complexity versus low-complexity traffic for drivers who listened to the radio

The results of the second mixed model ANOVA revealed that the recall percentage for the brand names heard during a drive in high complexity traffic (*M*= 29.01, *SD*= 13.92) was not significantly different from the recall percentage of brand names heard during a drive in low complexity traffic (*M*= 26.76, *SD*= 16.33), *F*< 1, *ns.*, η_p^2= 0.03. So, our second hypothesis regarding a lower percentage of recall from a drive in high complexity traffic was not confirmed for commercials. There was a significant main effect of order of starting the simulated driving with high or low complexity traffic on recall percentages, $F(1,30)= 6.13$, $p < .05$, η_p^2= 0.17. Percentage of brand names recalled was higher when the first drive took place in high complexity traffic (*M*= 32.46, *SE*= 2.79) than in low complexity traffic (*M*= 21.99, *SE*= 3.17). There was no interaction effect of order and complexity of the traffic on the percentage of brand names recalled; *F*< 1, *ns*., η_p^2= 0.03.

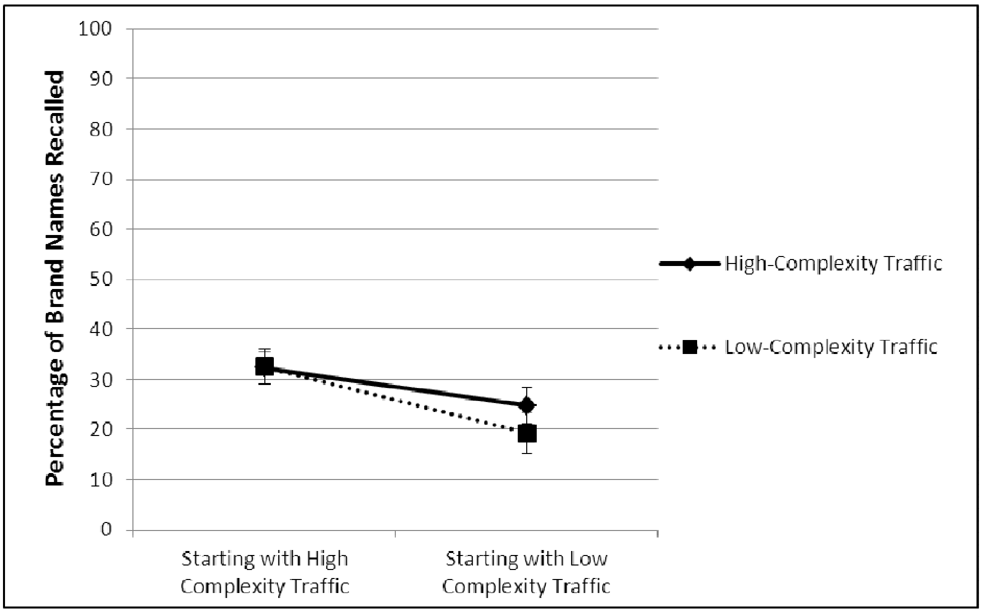

Figure 2. Percentage of brand names recalled during driving in high-complexity versus low-complexity traffic for drivers who listened to the radio

In terms of music excerpts, results revealed that there was no main effect of traffic complexity on the percentage of music excerpts recalled, $F(1,30)= 2.07$, $p= .16$, $\eta_p^2= 0.07$. So, the percentage of music excerpts recalled from a drive in high-complexity traffic ($M= 36.14$, $SD= 20.53$) was not significantly different from the percentage of music excerpts recalled from a drive in low-complexity traffic ($M= 32.11$, $SD= 19.54$). There were no significant main effect of order, and also no significant interaction effect, both Fs<1, *ns.*, and both $\eta_p^2< 0.01$. So, our second hypothesis regarding the lower recall performance from a drive in high-complexity traffic was not confirmed for music excerpts.

4. Discussion

In the current paper, we explored how drivers are able to maintain their driving performance while listening to the radio. In other words, we were interested in the mechanisms by which drivers cope with the distractions induced by a secondary task. We proposed that performing lower on the secondary task by blocking-out of radio content might be an effective strategy employed by drivers to reduce task demands resulting from driving and radio-listening. We formulated two hypotheses to examine whether task demands influence the way people pay attention to the radio. First, we hypothesized that the radio-content would be recalled less when radio-listening was accompanied by driving as compared to a situation in which radio-listening was not accompanied by driving, and thus, was hardly demanding. Second, we hypothesized that drivers in the radio-listening condition would recall less information from a radio broadcast during a drive in high-complexity traffic than during a drive in low-complexity traffic.

Prior to testing our hypotheses, we first confirmed that driving performance was indeed maintained by drivers while listening to the radio. In line with previous studies, we found that listening to music or the radio was not detrimental for driving performance (Ünal et al., 2012; Hatfield & Chamberlain, 2008; Strayer & Johnston, 2001; Turner et al., 1996). Then, how did radio-listeners sustain their driving performance? Did they down regulate their allocation of attention to the secondary task of radio-listening, so as to prioritize the main task of driving?

Our findings tapping on the differences between the recalled radio-content in Study 2 (radio-listening and driving) and Study 1 (radio-listening without driving) indicated that the driving task was indeed prioritized by our participants. As expected, participants with a driving task recalled less material from the radio-broadcast as compared to the participants who did not drive while listening to the radio. Importantly, this applied to all types of radio-content that we had used (namely talk-radio excerpts, commercials, and music excerpts). Therefore, our first hypothesis regarding lower rates of recall of the radio content due to driving was fully confirmed, meaning that the demands coming along with driving led to focusing less on the radio.

What about the situations in which the external demands are even higher due to traffic complexity? Is it likely that the radio content would be blocked-out further in those situations while driving? We examined this issue by comparing what has been recalled from the radio content during driving in busy and calm traffic settings.

Our second hypothesis, regarding a lower level of recall of the radio content during high-complexity traffic, was confirmed for only the talk-radio excerpts. As expected, drivers in the radio-listening condition tended to pay less attention to the talk-radio excerpts when the traffic demands were high. In terms of the commercials and music excerpts, recall of the radio-content did not differ based on traffic complexity manipulation.

Participants in Study 2 were slightly less familiar with the music excerpts that they had listened to as compared to the participants in Study 1. So, a lower familiarity with music might have led to a poorer recall of music excerpts in Study 2, regardless of the traffic complexity. In addition, memory processes might be functioning differently for music than for speech. For instance, there is evidence suggesting that lay listeners are quite good at reproducing the tempo of a song from memory with great accuracy (Levitin & Cook, 1996). Therefore, it is possible that people encode music fragments not based on song names, but based on more abstract features like its tempo or rhythm. Investigating the specific processes behind the retention of different audio-stimuli is beyond the scope of the current paper. However, it is of interest to replicate the current studies by using a different method to measure music memory, such as using a recognition task by playing instrumental versions of the excerpts to stimulate the retrieval of the abstract features of music (see Strayer, Drews, & Johnston, 2003, for a similar procedure applied to a visual task).

An alternative explanation for the lower recall percentages in Study 2 might be related to faster memory decay due to an increase in cognitive load of the participants while driving. That is, participants in Study 2 could have attended the radio content to the same extend as the participants in Study 1, but were not able to consolidate the information. We believe that this argument would be plausible if we had used a free recall task. However, we provided the participants with recall cues (i.e., presenting the brand names, artist names, and the topics discussed in talk-radio excerpts), and then measured how much they remembered, which makes it more likely that the lower recall rates are indeed related to paying less attention to the radio broadcast. That is because the recall cues would have triggered any information that had been attended but cannot be accessed due to memory decay. Still, the competing explanation regarding the influence of cognitive load on memory processes rather than attentional processes can be tested by future research, in order to have conclusive findings on blocking-out as a compensatory strategy while driving.

Previous literature has pointed out that a lower performance level in secondary tasks was suggestive of a high cognitive load while driving, and was used as an indication of increased mental effort (Cnossen et al., 2000; De Waard, 1996). In such situations, drivers either give up on the secondary task or start paying attention to the secondary task in a controlled manner as not to risk their driving performance (Schömig, Metz, & Krüger, 2011; Hockey, 1997). Our findings provided further evidence to the literature by showing that in the case of listening to the radio, primary task performance can be maintained by regulating one’s attention allocation to the radio. This was especially clear by our finding tapping on a higher inclination to block-out the talk-radio excerpts during high-complexity traffic. More research is needed to understand whether drivers employ this strategy consciously or not, in order to explore the mechanism further.

We would also like to note that there might be individual differences in employing cognitive strategies while multitasking in the car. For instance, there might be differences between younger and older drivers in terms of how they deal with distracters or secondary tasks, especially in demanding traffic conditions (Cantin, Lavalliere, Simoneau, & Teasdale, 2009; Chaparro, Wood, & Carberry, 2005). We had a sample of young drivers with moderate levels of driving experience, and our results showed that they paid less attention to the radio as compared to participants who did not have the concurrent driving task. It would be interesting to explore whether our results can be replicated in different samples, such as in samples with varying experience levels or among older drivers.

Lastly, in the current studies, we had to use the same radio broadcast in a predetermined sequence in order to have sufficient control over the presentation of the audio-stimuli, while this procedure did not fully reflect a normal radio-listening situation. So, it is possible that participants' engagement with the radio-program was lower than what is expected to be in real-life. Future studies could examine the effects of higher engagement radio-listening situations to further enhance our understanding of how blocking out works in real-life driving situations.

5. Conclusions

In the majority of the studies, scholars associated radio-listening with nonnegative experiences while driving (Hatfield & Chamberlain, 2008; Strayer & Johnston, 2001). Yet, little is known about how drivers maintain their driving performance while listening to the radio. The current research was one of the first that explored the mechanisms that enable drivers to maintain their driving performance while listening to the radio. First, we showed that individuals recall less material from a radio program when driving as compared to when not driving. This implies that drivers might be paying less attention on the radio. Second, our findings on poorer recall of the talk-radio excerpts when the traffic complexity was higher gave further support to the argument that drivers are able to regulate their cognitive resources based on the demands induced by the traffic environment. As a result, driving performance is maintained at a safe level. However, this should not be interpreted as radio being an undemanding type of auditory stimulus on the road. Rather, our results indicated that drivers employ cognitive strategies (i.e., blocking-out the radio) to deal with the mental load they experience due to driving with the radio on the background. The practical implication of our findings is that these strategies seem to be working quite fine, and drivers are able to prioritize the driving task, securing their driving performance constantly.

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Appendix

Description of Critical Driving Situations and Relevant Performance Indicators

In High-Complexity Traffic

1. Car emerging from the right (5-times): This scenario mirrored a hazardous driving incident in which another car unexpectedly emerged from a merging road to the right of the driver. The following performance indicators were used:

1.1. Maximum deceleration: The greatest deceleration value in m/s. Higher values of maximum deceleration indicate harder brake responses.

1.2. Minimum velocity: The smallest speed in m/s.

1.3. Maximum brake: The brake pedal position as a percentage from 0 to 100.

2. Car approaching from the left and violating the give-way rule (3-times): This scenario mirrored a hazardous driving incident in which another car approached from a merging road to the left of the driver. Although the driver had the right to pass through the intersection first, the other car did not stop, violating the give way rule. The performance indicators were the same as the car emerging from the right scenario.

3. Gap acceptance at an intersection: This scenario depicted a situation in which the participant had to cross an intersection where there were cars coming from left and right. The gap between the oncoming cars increases at a certain frequency. We were interested in the gap that the driver chooses to cross the intersection. The performance indicators for the situation were:

3.1. Accepted gap time: A measure in seconds, indicating the time between the movements of two oncoming cars. The higher the gap time, the longer the driver waited to cross the intersection.

3.2. Distance to cars that are approaching: It correlates with accepted gap time, and indicates of the distance between the two oncoming cars.

4. Car driving off from a parking lot (2-times): In this critical situation, a parked car unexpectedly drove off from a parking lot, and cut into the driver's way when the driver was passing. The driver was expected to brake immediately in order to avoid a collision. The following performance indicators were recorded:

4.1. Maximum deceleration (see 1.1)

4.2. Maximum brake (see 1.3)

4.3. Time to contact: The time in seconds that would lead to a collision to the first object in the same lane as the participant. It is calculated from the moment that the object appears on the road, which is the parked car driving off in this scenario.

5. Gap acceptance at a T-junction: The driver had to turn left in a T-junction in which there was oncoming traffic. The gap between the oncoming cars increased with a certain frequency. We were interested in the gap at which the driver chose to turn left. The performance indicators for the situation were the same as for the gap acceptance at an intersection scenario.

6. Oncoming car overtakes: The scenario was again mirroring a hazardous situation in which a car in the opposite lane overtakes another car, and suddenly appears on driver's own lane. The driver was expected to insert brake in order to be able to stop on time and avoid a possible head-on-crash with the overtaking car. The following performance indicators were recorded:

6.1. Length of the brake time: The time in seconds that is reflecting the length of using the brake pedal to decelerate.

6.2. Maximum brake (see 1.3.)

6.3. Time-to-contact: (see 4.3.)

In Low Complexity Traffic

1. Gap acceptance at an intersection: see number 3 above.
2. Car driving off from a parking lot: see number 4 above.

Chapter 4

Driving with Music:

Effects on Arousal and Performance

This chapter is based on Ünal, A.B., De Waard, D., Epstude, K., & Steg, L. (revised and resubmitted). Driving with music: Effects on arousal and performance. *Transportation Research Part F.*

Abstract

In the current study, we aimed at exploring the influence of music on driving performance, arousal and mental effort while carrying out a monotonous car-following task in a low-complexity traffic setting. Participants (N= 47) were randomly assigned to loud and moderate volume music groups, and completed one drive in the simulator with music and another drive without music (control condition). In addition, during both of the drives we monitored driving performance and recorded participants' heart rate to track physiological indications of arousal and mental effort. Results revealed that listening to music had no effect on accuracy of car-following, and even had a positive effect on response latencies to speed changes of the lead vehicle and on lateral control. Importantly, arousal was higher in the presence than absence of music irrespective of the volume level, suggesting that loud volume music was not more arousing than moderate volume music. In addition, mental effort, which was inferred from the physiological measurement of heart-rate variability, did not differ in conditions with and without music. These findings indicate that listening to music does not impair performance in a monotonous car-following task, and might even improve some aspects of performance as a result of increased arousal.

1. Introduction

Among the various secondary tasks that drivers engage in while driving, listening to music or the radio seems to be the most common activity accompanying the driving task (Dibben & Williamson, 2007). Interestingly, drivers report listening to music habitually, and simply for the purpose of killing time on the road (North, Hargreaves, & Hargreaves, 2004). Why do drivers need to kill time while driving? Can such a need for listening to music be related to the driving task not being sufficiently stimulating all the time? Indeed, the driving task can be monotonous at times, especially while driving in highly predictable environments that are low in complexity. Research indicated that such environments might elicit the experience of adverse driver states, such as boredom or drowsiness resulting from lack of external stimulation (Nelson, 1997; Thiffault & Bergeron, 2003). Importantly, such states might incline drivers to be prone to inattention errors, such as failing to notice changes in the traffic environment on time, which might increase accident-likelihood (NHTSA, 2008). Hence, monotonous driving conditions low in complexity can be quite challenging to handle, as drivers might find it hard to focus on the important aspects of the driving task due to the lack of arousal and stimulation. In the current paper, we explore whether listening to music might provide the external stimulation needed to defeat boredom and to keep focused on the driving task in situations where both the driving task and the traffic environment are monotonous, such as car-following in low-complexity traffic. Importantly, we not only study how music affects performance in such monotonous low-complexity situations, but also via which processes music influences driving performance.

Studies on music and driving typically regarded music as a secondary task that might be distracting. Various scholars examined to what extent music disrupts one's driving performance (Brodsky, 2002; Pêcher, Lemercier, & Cellier, 2009; North & Hargreaves, 1999, Beh & Hirst, 1999). Interestingly, in simulated driving studies, impairment in driving performance with the presence of music was seldom reported (Brodsky, 2002; Pêcher et al., 2009). In addition, in line with the premises of in-vehicle distraction literature, drivers were found to adopt cognitive or behavioural compensatory strategies to cope with increased task demands and protect their driving performance, especially when they were in high-complexity traffic settings or/and listened to demanding types of music (North & Hargreaves, 1999; Hughes, Rudin-Brown, & Young, 2013; Ünal, Steg, & Epstude, 2012; Ünal, Platteel, Steg, & Epstude, 2013). For instance, as indicative of cognitive compensations (see Hockey, 1997), drivers invested more mental effort when driving and listening to music in a high-complexity traffic setting, and prioritized the driving task by blocking-out radio-content to a large extent while driving (Ünal et al., 2012; Ünal et al., 2013). Also, drivers were found to have longer lap times in the presence of demanding types of music (i.e., high volume and high tempo) as compared to less demanding types of music (low volume and low tempo), meaning that they compensated for increased task demands by reducing their speed (North & Hargreaves, 1999). So, there is evidence suggesting that when the traffic demands or listening demands (or both) are high, drivers cope with the increased task demands by adopting compensatory strategies. In many cases, however, driving does not take place in complex environments. Indeed, driving often involves monotonous conditions that are very low in complexity, such as prolonged driving on rural roads or car-following. So, would drivers employ compensatory strategies while driving in low-complexity traffic settings as well? And how would music affect their driving performance?

To our knowledge, little is known about the influence of music on task performance in monotonous driving conditions. A study that examined the influence of loud music on driving performance in various conditions, including two driving tasks that took place in a highly-predictable environment (namely monotonous driving and car-following tasks, respectively), revealed that listening to loud music did not impair driving performance (Ünal et al., 2012). Specifically, music had no influence on the lateral control of participants in a monotonous driving task, while in a car-following task they even appeared to better respond to speed changes of the lead vehicle. These findings provided some preliminary evidence that the presence of music may increase vigilance while following a car in low complexity situations. However, the car-following task that was used in that study was relatively short (6 minutes), and was embedded in a hectic driving environment with many critical incidents, meaning that it was not depicting a boring driving situation. Hence, the questions of whether music would have no or positive effects on task performance in monotonous conditions in low-complexity settings and how performance is maintained in such conditions remain open.

Investigations regarding prolonged and monotonous driving conditions with the presence of other type of secondary tasks and in-vehicle distracters, such as talking on a mobile phone, indicate that such secondary tasks not necessarily impair driving performance. For example, although some studies showed a negative influence of using a mobile phone on car-following performance, as reflected by delayed responses to speed changes of the lead vehicle (Lamble, Kauranen, Laakso, &

Summmala, 1999; Alm & Nilsson, 1995; Brookhuis, De Vries, & De Waard, 1991; Brookhuis, De Waard, & Mulder, 1994), this tendency of having higher response latencies was absent while driving in low-complexity traffic with less perceptual load as compared to in high-complexity traffic (Strayer, Drews, & Johnston, 2003). In addition, lane-keeping performance, which is an indication of vehicle-control, was maintained in car-following tasks that were accompanied by a secondary task such as dialing a number or executing a working memory task on a mobile phone (Lamble, et al., 1999; Alm & Nilsson, 1995). Importantly, some studies revealed that car-control performance even improved in low-complexity driving situations with the presence of a secondary task as compared to when there was no secondary task (Atchley & Chan, 2011; Verwey & Zaidel, 1999; Brookhuis et al., 1991). For instance, drivers who had to carry out a concurrent mobile-phone task exhibited less swerving on the road as compared to drivers who did not have the additional mobile phone task (Brookhuis et al., 1991). So, these findings indicate that, different than observed in complex driving conditions, secondary tasks such as listening to music might not necessarily have adverse consequences on driving performance in monotonous conditions that are low in complexity. Then, through which processes will driving performance be maintained or even improved in the presence of a secondary task such as music?

As stated earlier, monotonous driving in situations characterized by low complexity is associated with low-arousal driver states such as boredom, drowsiness or fatigue, and drivers lack vigilance when they experience such states (O'Hanlon, 1981; Wertheim, 1991; Nelson, 1997; Thiffault & Bergeron, 2003). So, one potential explanation of performing well in monotonous conditions in the presence of secondary tasks is that these tasks can increase arousal to a more optimal level that would increase vigilance (Atchley & Chan, 2011; Heslop, Harvey, Thorpe, & Mulley, 2010). This argument is in line with predictions of the Yerkes-Dodson law (Yerkes & Dodson, 1908; Teigen, 1994), which posits that the relationship between task performance and arousal can be depicted by an inverted U-shaped curve. When one's arousal level is too high or too low, performance is predicted to be inhibited, while a moderate arousal level is expected to result in higher performance. Easterbrook (1959) explained this phenomenon by the cue-utilization theory, suggesting a link between arousal and attention. More specifically, Easterbrook (1959) argued that both under-arousal and over-arousal would have a negative influence on attention by impairing the efficient processing of the relevant cues needed to perform well on a task. However, a moderate level of arousal was associated with facilitating selective attention and the processing of relevant cues, resulting in a better performance attainment. Based on Easterbrook's framework, we assume that in monotonous driving situations that are low in complexity, drivers would experience under-arousal due to the absence of external stimulation, which would impair their attentional processes. In such situations, performance might benefit from an external stimulation source, such as music, which would increase the arousal closer to optimal in monotonous situations, and thereby facilitate attention on the main task.

Research suggests that increases in arousal would particularly improve performance in easy tasks and less so in difficult tasks (McGrath, 1963; Beh & Hirst, 1999) because an arousing stimulus would influence mental workload and demands on information processing differently in simple and complex tasks. For instance, in difficult and complex tasks an additional arousing stimulus (e.g. loud noise) might increase mental workload above the ideal level, thereby competing for the cognitive capacity needed for primary task performance (Boggs & Simon, 1968; Konečni & Sargent-Pollock, 1976; Beh & Hirst, 1999). As a result, we might expect mental effort to increase due to task-related factors (e.g., task-demands). In relatively easy and monotonous tasks, however, performers have a higher threshold for arousal, and therefore, an arousing stimulus can be tolerated well (Yerkes & Dodson, 1908). Interestingly, for monotonous tasks, an increase in mental effort might be expected when the arousal level is below ideal and when the performer is deactivated due to feelings of fatigue or boredom (Warm, Parasuraman, & Matthews, 2008; Warm, Dember, & Hancock, 1996; De Waard, 1996; Hancock & Verwey, 1997). This type of effort mobilized as a consequence of monotony is called state-related effort or compensatory effort (see De Waard & Brookhuis, 1997; G. Mulder, 1986), meaning that drivers are inclined to invest more effort in the driving task in order to keep focused despite being bored or fatigued. Based on this reasoning, we assume that in highly monotonous tasks, increases in arousal might lead to a decrease in required mental effort investment by reducing state-related demands (i.e., fighting boredom or fatigue), which may increase vigilance, as a result of which driving performance would be secured. Can music provide the drivers with adequate levels of arousal that is needed to handle dull monotonous driving tasks?

Music, and especially some aspects of music that are associated with high energy such as loud and high tempo music, has been documented to increase self-reported and physiological arousal (Dalton, Behm, & Kibele, 2007; Husain, Thompson, & Schellenberg, 2002; North & Hargreaves, 1999; Konečni & Sargent-Pollock, 1976; Fontaine & Schwalm, 1979; Davenport, 1972; McNamara & Ballard, 1999). However, little is known about the relationship between music and arousal in monotonous driving conditions. Similarly, although there is preliminary evidence suggesting that in high-complexity environments music might increase mental effort by competing for the shared resources needed for the driving task (Ünal et al., 2012), to our knowledge, as yet no study tested how mental effort is affected by music in monotonous driving conditions that are very low in complexity. In the current study, we aim at investigating these issues by employing a monotonous car-following task that takes place in a low complexity traffic setting, and examine how music-induced arousal would affect driving performance, arousal, and mental effort in such settings. In addition, as individuals might have a higher threshold for arousal when busy with tasks that are not complex (McGrath, 1963; Yerkes & Dodson, 1908), we will manipulate the loudness of music in an attempt to test whether loud volume music (i.e., 85dB) with a higher arousal potential will improve performance on a monotonous car-following task more than moderate volume music (i.e., 70dB) with a lower arousal potential. Studies suggested that both arousal and mental effort can be inferred from physiological changes, and especially, by changes in heart-rate (arousal) and heart-rate variability (mental effort; Dalton, et al., 2007; L. Mulder, De Waard, & Brookhuis, 2005). So, in the current study, we will not only assess arousal by self-reports but also by means of heart-rate data. In addition, heart rate (variability) information will be used to track changes in mental effort.

Based on the above, and in line with the Yerkes-Dodson law (1908) and findings on the positive or nonnegative effects of secondary tasks on performance in monotonous tasks (Brookhuis et al., 1991; Heslop et al., 2010; Mayfield & Moss, 1989), we hypothesize that listening to music will either have no effect or positive effects on performance in a monotonous car-following task (Hypothesis 1). Hence, we expect that music will not impair car-following performance. Second, based on the premises of the cue utilization theory (Easterbrook, 1959), we hypothesize that the arousal level of the participants, as measured by both self-reports and the physiological indicator mean heart rate, will be higher when the monotonous driving task is accompanied by music as compared to when it is not accompanied by music (Hypothesis 2a). We further hypothesize that the expected influence of music on arousal will be more pronounced when driving with loud volume music as compared to when driving with moderate volume music (Hypothesis 2b). Lastly, in line with the literature on increased mental workload in monotonous driving conditions that are low in complexity (see De Waard, 1996), we hypothesize that mental effort as inferred from the physiological indicator heart-rate variability will be higher in the absence of music than in the presence of music (Hypothesis 3).

2. Method[6]

2.1. Participants

Fifty-two psychology students of the University of Groningen participated in the study in exchange of course credits. Five of the participants suffered from simulation sickness, and could not complete the simulated drive. Therefore, data analyses were carried out with the remaining 47 participants (21 female, 26 male) whose age ranged from 19 to 25, with a mean age of 20.7 (SD= 1.34). Participants' mean driving experience was 2.6 years (SD= 1.61), and they drove on average 5107

[6] The study was approved by the Ethics Committee of the University of Groningen

kilometres in the year preceding the study (SD= 5850). None of the participants reported having any hearing deficiencies.

2.2. Experimental Design

The study employed a 2 (driving with and without music) by 2 (group: listening to loud or moderate volume music) mixed-subjects design with repeated measures on the first factor. The repeated measures involved two assessments in the driving simulator: an experimental condition with music and a control condition without music; the order of these sessions was counterbalanced. The between factor, which was labelled as "group", involved listening to music with either loud (85dB) or moderate volume (70dB); participants were randomly assigned to one of the music volume groups[7]. In all assessments, the same driving route was used which was monotonous and low in complexity. In order to avoid possible learning effects, there was at least a two-week interval between the first and second assessments of the participants.

2.3. Driving Simulator and Driving Environment

The driving simulator of the Psychology Department of the University of Groningen (StSoftware) was used, which had a usual car-control interface. The simulator was surrounded by four LCD screens, providing a 240 degrees view of the traffic environment. The data were recorded in the database of the main computer with a sample rate of 10Hz. (see Van Wolffelaar & Van Winsum, 1995). The simulated world depicted an intercity driving situation, in which drivers were on a single carriageway consisting of two lanes. Participants had to execute a car-following task in the simulator. As we aimed at inducing monotony through the car-following task, we kept the car-following task relatively uninterrupted and longer (30 minutes) than in previous research (Alm & Nilsson, 1995; Lamble et al., 1999). The lead car that

[7] There were no systematic differences between the groups in terms of age (F<1, ns) and driving experience measured by the annual km driven in the year preceding the study (F<1, ns). In addition, the gender distribution was the same in the groups, meaning that both groups held similar characteristics.

was placed on the lane of the participant had a variable speed that ranged between 60-80 km/h. The phase-length (length of accelerations and decelerations) ranged between 10-40 seconds randomly. In order to prevent the participants from overtaking the lead car out of boredom, there was oncoming traffic in the opposite lane at all times. The oncoming traffic was programmed in such a way that other vehicles never posed threat on the driver. In addition, both the speed of the vehicles and the distance between the vehicles was fixed. As such, we ensured that the traffic environment was highly predictable and monotonous.

2.4. Music Stimuli

In order to ensure the ecological validity of music-listening, we did not use a specific playlist in the current study. Rather, participants created their own playlist at the beginning of the experimental session, by using an online music library. This methodology ensured high familiarity with and liking of music while driving, and therefore any effects observed on driving performance or heart-rate measures would not be related to being unfamiliar with the music or disliking the music. We checked whether we indeed succeeded in having everyone listening to their preferred type of music by asking participants to indicate the extent to which they liked the music. Responses were given on a 5-point Likert type scale (1= totally disagree, 5= totally agree)[8].

2.5. Dependent Measures

2.5.1. Driving Performance Indicators

The main performance indicator for car-following was delay in response (sec.) which is a measure reflecting the delay in seconds in terms of responding to accelerations and decelerations of the lead vehicle. Specifically, delay in response

[8] Inspection of the ratings revealed that participants reported a high liking for the music they listened to (*M*=4.7, *SD*= 0.54). Importantly, there was no difference between the moderate and high volume groups in terms of liking the music ($F < 1$, ns.), meaning that regardless of the loudness of the music, all participants enjoyed the songs they listened to.

was determined from the phase shift between the speed signal of the lead and following vehicle. However, in order for delay to be calculated correctly, the precondition of following the lead car coherently should be met (see De Waard & Brookhuis, 2000). Therefore, we also monitored coherence, which reflects the accuracy of car following as reflected in the correlation between the speed signals of the participant's car and the lead car. Hence, coherence values could range from 0 (no relation) to 1 (perfect relation), with higher value reflecting more accurate following of the lead-car's speed changes. Brookhuis and colleagues (1994) suggested 0.70 to be a sufficiently high value for coherence. In the current study, we set this threshold to 0.60 in order not to exclude the participants who performed moderate to high. Individual scores for these car-following performance indicators were calculated by using the CARSPAN program, which uses the speed signals of the lead and following vehicles in calculating "the co-occurrence of rhythmic changes in two signals measured" (p. 428; Brookhuis et al., 1994). Mean coherence and delay scores were computed for every 5-minutes of the 30-minute simulated drive. Therefore, we calculated six delay and six coherence scores for each drive, allowing us to detect any changes in car-following performance over time as well (i.e., time-on-task effects).

In addition to these specific indicators of car-following, participants' lateral control was recorded by assessing the standard deviation of lateral positioning (SDLP in meters) on the road, which is a general indicator reflecting lane-keeping performance (O'Hanlon, Haak, Blaauw, & Riemersma, 1982). Three SDLP values were calculated automatically by the data processing tool of the simulator. As a consequence, lateral control is reflected in 10 rather than 5-minute intervals (i.e., 0-10 min, 10-20 min and 20-30 min). The lower the SDLP scores, the better one's lane keeping performance.

2.5.2. Physiological Measures of Arousal and Mental Effort

Participants' electrocardiogram (ECG) was measured by using three Ag- AgCl electrodes; one of them placed at the sternum, the other two placed in between the two lower ribs on the right and left. The ECG signal was recorded with a sampling rate of 250 Hz. R-peaks were detected online using Portilab (version 1.10, Twente Medical Systems International) with an accuracy of one millisecond. Data were checked on artefacts and corrected automatically (using the CARSPAN spectral analysis program), and were visually inspected (see L. Mulder, 1992). Spectral analysis of the cardiovascular data was performed with the CARSPAN program (L. Mulder, 1992). The first three and the last three minutes of the ECG data were resting measurements (labelled Resting 1 and Resting 2). For resting and experimental sections, mean heart rate and heart-rate variability in the mid (0.07-0.14 Hz) frequency band were computed, the former as an indication of arousal and the latter of mental effort (see L. Mulder, 1992).

Similar to the procedure with the car-following performance indicators, mean heart rate and heart rate variability scores were recorded based on 5-minute intervals of the 30-minute driving task. As such, we calculated eight scores (two resting measures and six task measures) for mean heart rate and heart rate variability for each simulated drive (i.e., the drive with music and without music), reflecting changes in heart rate over time. In addition, overall means for heart-rate and heart-rate variability (over 30 minutes) were calculated to compare heart-rate recordings during the driving task to the resting periods in order to check whether heart rate recordings were sensitive to driving task-characteristics and the presence of music while driving.

2.5.3. Self-Reported Deactivation after the Simulated Drives

Subjective arousal level was measured by using an explicit self-reports tapping on relevant emotions in terms of deactivation in monotonous driving conditions. Specifically, the measure consisted of three emotions that depict negative valence and low-arousal in Russell's Circumplex Model of Affect (1980), namely bored, tired and sleepy. In addition, we also included the item energized that depicts positive valence and high-arousal, which was used as a reverse item for drowsy. Participants indicated to what extent they felt bored, tired, sleepy and energized after the simulated drive on a Likert-type scale (1=strongly disagree, 7=strongly agree).

The item energized was reverse coded. A factor analysis revealed that all four items loaded on a single factor, which we labelled deactivation. The scale had an acceptable level of reliability (Cronbach's alpha = .70). So, mean scores were calculated reflecting the self-reported deactivation level during the drives with music and without music; higher scores reflect higher self-reported deactivation.

2.6. Procedure

We followed the same procedure in all assessments. Participants were instructed that they were going to complete a driving session in the simulator during which their heart rate would be recorded. At this point, participants in the music condition were informed that they would listen to music while driving, and they were asked to create a playlist representative of what they like to listen to on the road. Prior to both of the simulated driving session, all participants received training in the simulator. The training took approximately 5 minutes to complete, and involved a car-following task. Participants were instructed to follow the lead car's speed changes as good as possible, while maintaining a safe headway to it. Participants who were observed not to conform with the instructions were instructed further during the training that they should always follow the lead car by having a close but safe distance, meaning that all participants got acquainted with the task of car-following before the experimental session began. Participants drove in the simulator for 30 minutes each drive during which their heart rate was recorded. In addition, we also had two resting heart-rate measurements for each drive: one before starting to drive in the simulator, and another one right after the drive (see 2.5.2). The resting periods were not accompanied by music. After the second resting heart-rate measurement, participants were seated behind a desk, and they filled in the self-reported deactivation scale (see 2.5.3.). After a drive with music, participants also completed a brief questionnaire on whether they indeed liked the music they had listened to (see 2.4.).

2.7. Analyses

The analyses included within-subjects comparisons in the music and no-music conditions, and between group comparisons of the music volume groups. Therefore, we used mixed-ANOVA for data analyses. Specifically, we first ran an overall mixed-ANOVA to check whether the multivariate test was significant. When the multivariate test results were significant, we ran separate mixed-ANOVAs to explore the differences within conditions in car-following performance, mean heart-rate and heart rate variability (which were measured over 5 minute intervals), and standard deviation of lateral positioning (which was measured over 10-minute intervals). Partial eta square (η_p^2) was used to report the effect sizes, and a significance level of .05 was set for statistical significance.

Prior to analysing the data on car-following performance indicators, we inspected the data to identify participants who failed at following the lead car coherently. Inspection of the data revealed that thirteen participants (7 from the loud volume music and 6 from the moderate volume music group) had coherence scores below 0.60 in almost all instances of car-following, and in both of the assessments. These participants were not included in the analyses regarding car-following because they did not perform the car following task according to instructions. Hence, the analyses of car-following performance were carried out with the remaining 34 participants. Finally, inspection of the heart-rate recordings revealed two participants whose heart rate data showed a high number of artefacts resulting from technical problems during the recording process. These participants were excluded from the analyses regarding the heart-rate measures.

3. Results

3.1. Car-following performance

3.1.1. Accuracy in car-following (coherence)

Initially, an overall mixed-ANOVA was run with all six coherence scores in the music and no-music conditions as a within-subjects factor, and group as a between-groups factor. Results revealed a significant multivariate effect for coherence (F(11,22)= 2.77, p< .05), which implies that there might be within-subjects differences while driving with music and without music over a 30-minute long drive. In addition, we found a significant group difference in coherence (F(1,32)= 8.62, p< .01, η_p^2= 0.21). The interaction of the presence of music and volume of music, however, was not significant (F< 1, *ns*). We explored the differences in coherence while driving with and without music in more detail by running separate mixed-ANOVAs for each of the 5-minute intervals of the simulated drive. As can be seen in Table 1, there was no main effect of the presence of music on coherence in any of the 5-minute intervals (all Fs < 1, ns). However, there was a main effect of group on coherence during all intervals (see Table 1): regardless of the presence or absence of music, participants who were in the loud volume music group followed the lead car more coherently than participants who were in the moderate volume music group (see Figure 1). Again, there were no interaction effects of the presence of music and music volume (F values ranging from 0.09 to 1.34; all being non-significant at p< .05; see Table 1). In non-statistical terms, these results indicate that the main effect of group resulted from initial differences among participants in each group, and not because of the volume of the music.

Together, the findings gave support to the first hypothesis, as participants were able to follow the lead car accurately both with music and without music, indicating that the presence of music did not impair car-following performance. Also, loudness of the music did not significantly affect car-following performance. Next, we examined whether the same pattern would be observed for the main performance indicator: delay in response in car-following.

Table 1. Results of a Mixed-ANOVA: F-Statistics for the Heart Rate Measurements and Driving Performance Indicators

	Mean Heart-Rate			Heart Rate Variability			Coherence			Delay		
	df	F	η_p	df	F	η_p	df	F	η_p^2	df	F	η_p^2
Resting 1												
Music/No-Music	1,42	0.44	.01	1,42	1.66	.04						
Amplitude	1,42	0.13	.00	1,42	0.21	.01						
Music/No-Music x Amplitude	1,42	0.20	.00	1,42	0.81	.02						
Car-Following Task												
0-5 minutes												
Music/No-Music	1,43	8.18**	.16	1,43	0.44	.01	1,32	0.00	.00	1,32	5.46*	.15
Amplitude	1,43	0.16	.00	1,43	0.10	.00	1,32	3.54$^{\delta}$	.10	1,32	4.47*	.12
Music/No-Music x Amplitude	1,43	0.12	.00	1,43	0.00	.00	1,32	0.26	.00	1,32	0.09	.00
5-10 minutes												
Music/No-Music	1,43	5.77*	.12	1,43	2.23	.05	1,32	0.48	.02	1,32	9.20**	.22
Amplitude	1,43	0.17	.00	1,43	0.00	.00	1,32	9.12**	.22	1,32	5,14*	.14
Music/No-Music x Amplitude	1,43	0.28	.00	1,43	1.51	.03	1,32	0.09	.00	1,32	2.01	.06
10-15 minutes												
Music/No-Music	1,43	5.85*	.12	1,43	0.45	.01	1,32	0.45	.01	1,32	14.41**	.31
Amplitude	1,43	0.15	.00	1,43	0.08	.00	1,32	5.70*	.15	1,32	5.21*	.14
Music/No-Music x Amplitude	1,43	0.25	.01	1,43	0.01	.00	1,32	0.33	.01	1,32	6.52*	.17
15-20 minutes												
Music/No-Music	1,43	3.93$^{\sigma}$	.08	1,43	0.18	.00	1,32	0.05	.00	1,32	8.27**	.20
Amplitude	1,43	0.18	.00	1,43	0.79	.02	1,32	6.36*	.17	1,32	4.44*	.12
Music/No-Music x Amplitude	1,43	0.01	.00	1,43	0.94	.02	1,32	0.14	.00	1,32	2.45	.07
20-25 minutes												
Music/No-Music	1,43	3.16	.07	1,43	0.01	.00	1,32	0.77	.02	1,32	4.30*	.12
Amplitude	1,43	0.06	.00	1,43	0.07	.00	1,32	6.10*	.16	1,32	4.20*	.12
Music/No-Music x Amplitude	1,43	0.01	.00	1,43	1.84	.04	1,32	0.10	.00	1,32	0.80	.02
25-30 minutes												
Music/No-Music	1,43	2.34	.05	1,43	0.01	.00	1,32	0.78	.02	1,32	4.23*	.12
Amplitude	1,43	0.02	.00	1,43	0.60	.01	1,32	4.06$^{\sigma}$	.11	1,32	1.37	.04
Music/No-Music x Amplitude	1,43	0.05	.00	1,43	0.25	.01	1,32	1.34	.04	1,32	0.02	.00
Resting 2												
Music/No-Music	1,43	1.66	.04	1,43	1.01	.02						
Amplitude	1,43	0.17	.00	1,43	1.43	.03						
Music/No-Music x Amplitude	1,43	0.31	.01	1,43	0.00	.00						
n			45						34			

Note. * $p < .05$, $^{\sigma}$ $p = .05$, ** $p < .01$, $^{\delta}$ marginally significant at $p < .07$

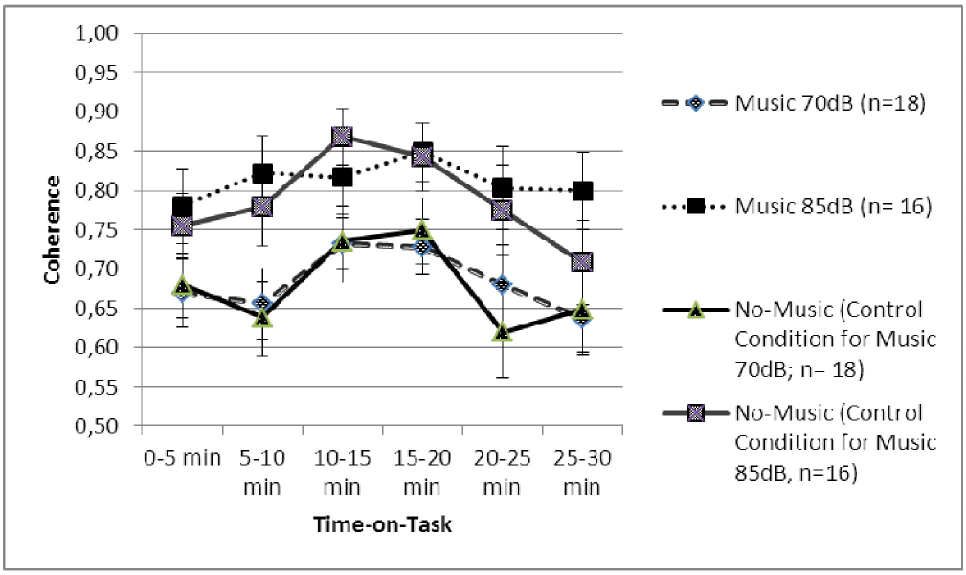

Figure 1. Coherence in car-Following while driving with and without music in loud and moderate volume music groups. Bars represent the standard errors for the means.

3.1.2. Differences in delay in response in car-following

An overall mixed-ANOVA was run with the mean delay scores during the 5-minute intervals in the music and no-music conditions as a within-subjects factor, and group as a between-groups factor. Results revealed a significant multivariate effect for delay in response to the speed changes of the lead vehicle (F(11,22)= 3.30, p< .01), which implies that there might be within-subjects differences while driving with music and without music over a 30-minute long drive. In addition, we found a main effect of group on delay (F(1,32)= 5.28, p< .05, η_p^2= 0.13) while the interaction term was again not statistically significant (F(11,22)= 1.07, *ns*). As the overall mixed-model ANOVA revealed significant multivariate effects, delay scores were further investigated by running separate mixed-ANOVAs for each 5-minute interval of the car-following task. Supporting the first hypothesis, the results revealed a significant main effect of the presence of music in all six parts of the car-following task (see Table 1). It appeared that participants responded faster to the speed changes of the lead car when they listened to music while driving than when there was no-music (see Figure

2). There was a significant main effect of group on delay during the first 25 minutes of the car-following task (see Table 1). Regardless of the presence or absence of music, participants who were in the loud volume music group responded faster to the speed changes of the lead vehicle as compared to the participants who were in the moderate volume music group, again suggesting initial differences between groups (see Figure 3). Lastly, we observed a significant interaction effect of the presence of music and group on delay for the third part of the car-following task (i.e., 10-15 minutes). Contrast analysis revealed no significant differences in delay between the groups while driving with music. However, when driving without music, the loud volume music group responded faster to the speed changes of the lead vehicle (M= 3.3, SE= 0.51) as compared to the moderate volume music group (M= 5.2, SE= 0.48; $F(1,32)$= 7.28, $p < .05$).

We also checked whether there was an effect of time-on-task on delay in response while driving with music and without music. A mixed-ANOVA with all six scores reflecting the delay scores in every 5-minute of driving revealed no main effect of time-on-task on delay while listening to music ($F(5,220)$= 1.32, *ns*., η_p^2= 0.03). So, in the presence of music, delay did not change significantly over time. Also, group had no main effect on delay scores ($F < 1$, *ns*.) and the interaction of group and time-on-task was not statistically significant either (F (5,220)= 1.15, *ns*, η_p^2= 0.03). A second mixed ANOVA with the six delay scores while driving without music revealed a significant main effect of time-on-task ($F(5,225)$= 2.57, $p < .05$, η_p^2= 0.05). However, contrast analysis did not reveal a significant linear or quadratic trend for this effect. There was no main effect of group on delay scores while driving without music ($F < 1$, *ns*), and the interaction of group and time-on-task was not statistically significant either ($F < 1$, *ns*).

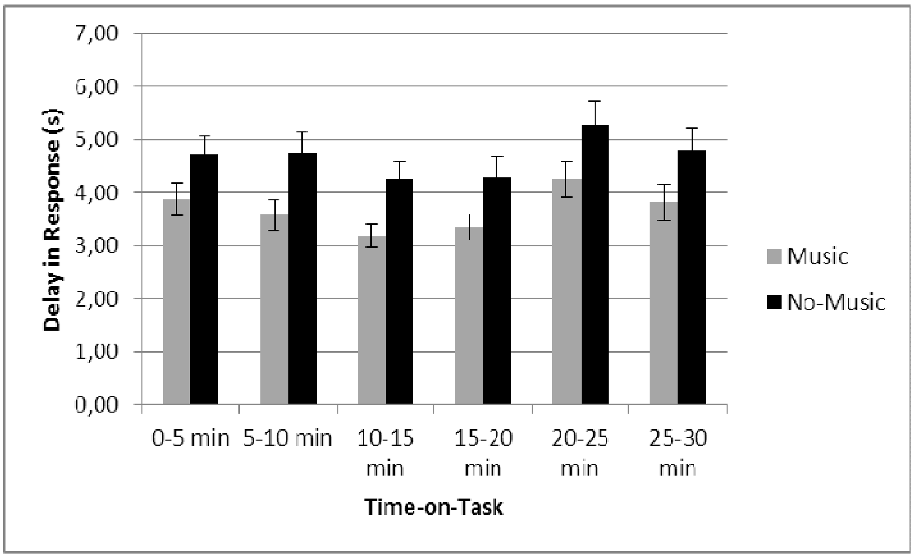

Figure 2. Delay in response while following a lead car when driving with and without music. Bars represent the standard errors for the means (n=34).

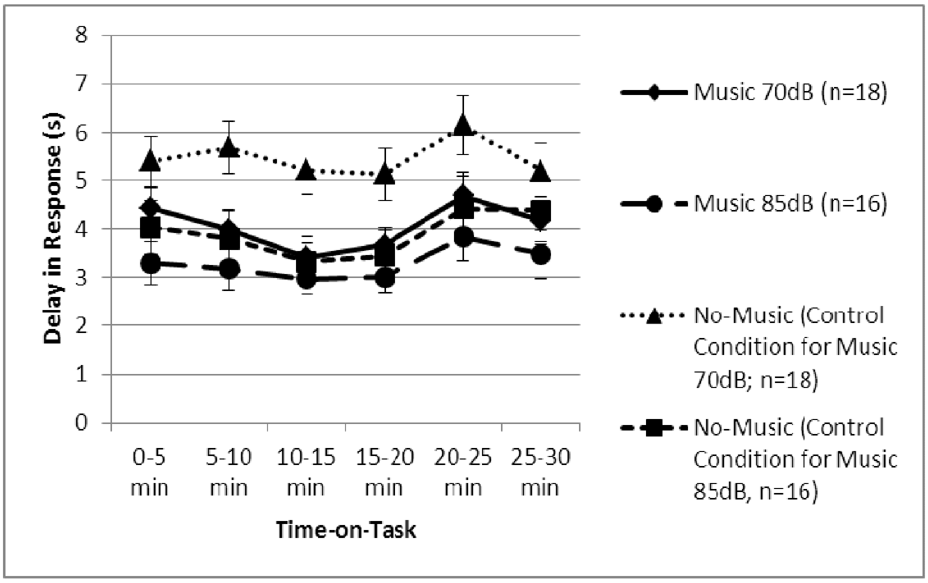

Figure 3. Delay in car-following while driving with and without music in loud and moderate volume music groups. Bars represent the standard errors for the means.

3.1.3. Effect of music on standard deviation of lateral positioning

Standard deviation of lateral positioning (SDLP) was checked as a general indicator of driving performance during car-following with and without music. First, an overall mixed-ANOVA was run with the SDLP scores while driving with music and without music as a within-subjects factor and group as a between groups factor. Results revealed a significant multivariate effect for standard deviation of lateral positioning ($F(5,27)= 3.30$, $p< .05$). There was no main effect of group on the SDLP scores ($F< 1$, *ns*.), and the interaction term was not significant either ($F(1,31)= 1.46$, *ns*).

We then ran separate mixed-ANOVAs for all three sections of the road in order to further explore the differences in lane-keeping performance with music and without music. Results revealed significant main effects of the presence of music on SDLP during the last two time intervals (see Table 2). Supporting Hypothesis 1, participants had a slightly smaller standard deviation of lateral positioning while driving with music than while driving without music during 10-20 minutes ($F(1,31)= 6.27$; $p< .05$) and 20-30 minutes ($F(1,31)= 6.03$; $p< .05$) of the car-following task, while SDLP during the first ten minutes of car-following did not differ between conditions with and without music ($F(1,31)= 1.22$, *ns*). Finally, there was no main effect of group on standard deviation of lateral positioning, and no interaction of the presence of music and group on the SDLP scores in any of the time intervals (see Table 2). Inspection of time-on-task effects revealed no effects for drives with music and without music either ($F(2,62)= 1.76$, *ns* and $F(2,64)= 1.42$, *ns* respectively).

Table 2. Mixed-ANOVA Results for Standard Deviation of Lateral Positioning (SDLP) during 10-Minute Intervals of the Car-Following Task with and without Music

	SDLP(m)		SDLP(m)		df	F	η_p^2
	Music (70dB) Mean	No-Music(70dB) Mean	Music (85dB) Mean	No-Music(85dB) Mean			
Car-Following Task							
0-10 minutes							
Music/No-Music	0.25 (.09)	0.25 (.06)	0.25 (.07)	0.27 (.07)	1,31	1.22	.04
Amplitude					1,31	0.34	.01
Music/No-Music x Amplitude					1,31	1.39	.04
10-20 minutes							
Music/No-Music	0.24 (.07)	0.25 (.07)	0.24 (.05)	0.28 (.08)	1,31	6.27*	.17
Amplitude					1,31	0.32	.01
Music/No-Music x Amplitude					1,33	2.43	.07
20-30 minutes							
Music/No-Music	0.25 (.06)	0.27 (0.8)	0.24 (.05)	0.27 (.06)	1,31	6.03*	.16
Amplitude					1,31	0.00	.00
Music/No-Music x Amplitude					1,31	0.44	.01
n	18		15				

Note. Values in parentheses are the standard deviations for mean SDLP (m).
* $p< .05$

3.2. The effect of music on self-reported deactivation after the simulated drives

A mixed-ANOVA revealed a main effect of the presence of music on self-reported deactivation ($F(1,45)= 55.33$, $p<.001$, $\eta_p^2 = 0.55$). As expected (Hypothesis 2a), participants reported being less deactivated (i.e., more aroused) while driving with music ($M= 3.69$, $SD= 1.16$) than without music ($M= 5.01$, $SD= 0.94$). The analysis did not reveal a main effect of group on deactivation ($F(1,45)= 2.12$, *ns*.). However, a statistically non-significant trend towards an interaction effect between the presence of music and music volume group was found ($F(1,45)= 3.86$, $p=.06$, $\eta_p^2= 0.08$). Specifically, in line with Hypothesis 2b, after a drive with music, participants who listened to loud volume music scored lower on deactivation ($M= 3.33$, $SD= 1.26$) as compared to those who listened to moderate volume music ($M= 4.03$, $SD= 0.94$). After a drive without music, however, participants in both groups scored equally high in self-reported deactivation ($M=5.01$, $SD= 0.85$ and $M=5.01$, $SD= 1.04$, respectively for the no-music condition of 85dB and 70dB volume groups). In non-statistical terms, loud volume music showed the expected pattern of being more arousing than moderate volume music, while however, this difference was not significant and remained as a trend.

3.3. The effect of music on mean heart rate

Prior to testing for the differences between mean heart rate while driving with and without music, we first checked whether there were systematic differences in mean heart rate during resting periods and driving. As such, we aimed at exploring the sensitivity of the heart rate measurement, because a difference between task and resting periods would reflect that mean heart rate was sensitive to task-related factors. Results of an overall mixed-ANOVA revealed a significant within-subject difference in mean heart rate between task and resting periods ($F(5,210)=7.57$, $p< .001$, $\eta_p^2= 0.15$). Repeated contrasts revealed that when driving without music, mean heart rate while driving ($M= 81.49$, $SD= 11.92$) was significantly higher than the mean heart rate during the Resting 2 period ($M= 77.68$, $SD= 10.68$; $F(1,42)= 36.56$, $p< .001$), but not significantly different from the mean heart rate during the Resting 1 period ($M= 81.57$, $SD= 13.56$; $F< 1$, *ns*). So, participants' heart rate during driving did not differ from the first baseline measure, while however, it differed from the second baseline measure, with a decrease in average heart rate about 4 beats/minute in Resting 2. Contrasts analyses further revealed that for the drive with music, mean heart rate during the driving task ($M= 84.64$, $SD= 12.39$) was significantly higher than in the Resting 1 ($M= 82.69$, $SD= 12.79$; $F(1,42)= 6.90$, $p< .05$) and Resting 2 ($M= 79.17$, $SD= 12.26$; $F(1,42)= 71.70$, $p< .001$) periods. The findings thus indicated that the heart-rate measure was sensitive to driving task characteristics as well as to the presence of music accompanying the task.

Next, we compared the mean heart rate of the participants during the 30-min task period in the conditions with and without music. A mixed-ANOVA revealed that mean heart rate of the participants was approximately 3 beats/minute higher while driving with music ($M= 84.2$, $SD= 12.62$) than while driving without music ($M= 81.0$, $SD= 12.38$; $F(1,43)= 5.12$, $p< .05$; $\eta_p^2= 0.10$). Therefore, in line with the Hypothesis 2a, listening to music increased arousal while driving.

We further explored in which part of the simulated drive mean heart rate was significantly different while listening to music while driving as compared to driving without music. Separate mixed-model ANOVAs were run for each time interval as well as for the resting measurements. As can be seen in Figure 4, participants' mean heart rate was significantly higher for the first 20 minutes of the 30-minutes long simulated drive when driving with music as compared to when there was no-music (see Table 1). For the last 10 minutes of driving, this trend of a higher mean heart rate while driving with music remained, but the differences were only marginally significant. There were no interaction effects, and no differences between the groups who listened to music with volumes of 85dB versus 70dB. So, Hypothesis 2b on loud volume music being more arousing than moderate volume music was not supported (see Table 1).

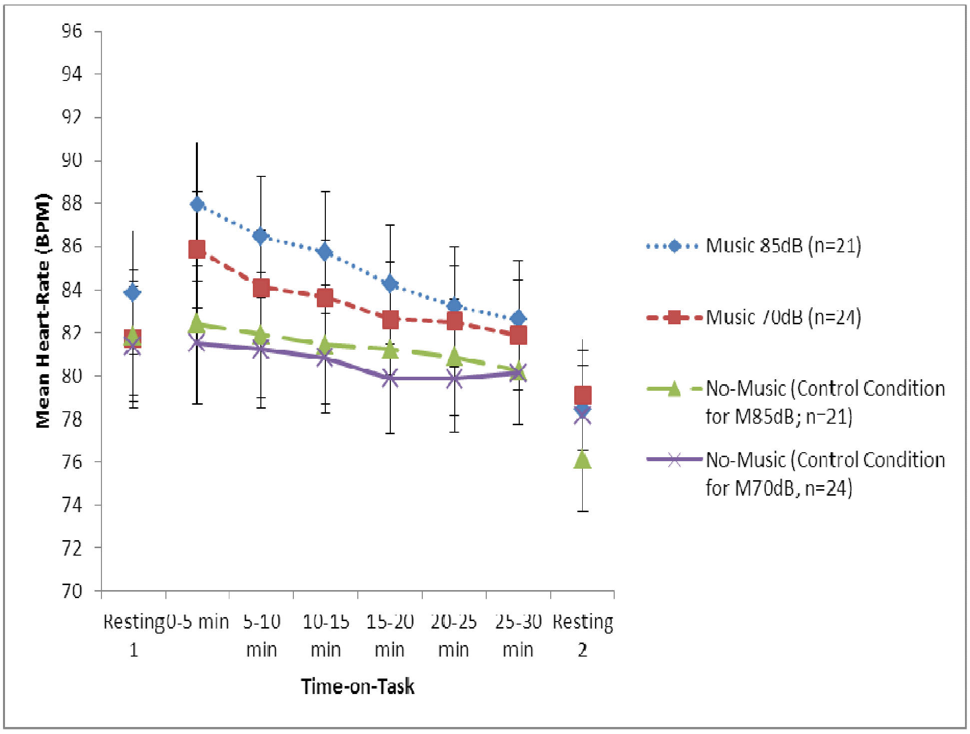

Figure 4. Mean heart-rate while driving with and without music in loud and moderate volume music groups. Bars represent the standard errors for the means.

We further depicted how the volume of the music affected mean heart rate of participants by calculating difference scores by subtracting the mean heart rate in the condition without music from the mean heart rate in the condition with music. As seen in Figure 5, the difference scores were always different from 0 for both volume groups. Visual inspection of Figure 5 also shows that the difference in mean heart rate when driving with music and without music was approximately one-beat higher for the loud volume music group as compared to moderate volume music group during the first half of the driving task.

We also see that the difference in mean heart rate with music and without music diminished over time, suggesting a habituation effect for both groups (see Figure 5). Indeed, an overall mixed-ANOVA revealed a main effect of time-on-task on mean heart rate while driving with music (F(5,225)= 27.32, p< .001, η_p^2= 0.38). Contrast statistics revealed a significant linear trend (F(1,45)= 48.53, p< .001, η_p^2 = 0.52), indicating a decrease in mean heart rate as an effect of time-on-task while driving with music. There was no main effect of group (F<1, *ns*), and no interaction effect of group and time-on task (F(5,225)= 1.32, *ns*) on mean heart rate. A second overall mixed-ANOVA was run for the condition without music. The results of the analysis again revealed a main effect of time-on-task on mean heart rate while driving without music (F(5,215)= 3.96, p< .01, η_p^2 = 0.08). Contrast statistics revealed a significant linear trend again (F(1,43)= 4.85, p< .05 η_p^2= 0.10), suggesting a decrease in mean heart rate over time. There was no main effect of group (F<1, ns) and no interaction effect of group and time-on-task (F<1, ns) on mean heart rate.

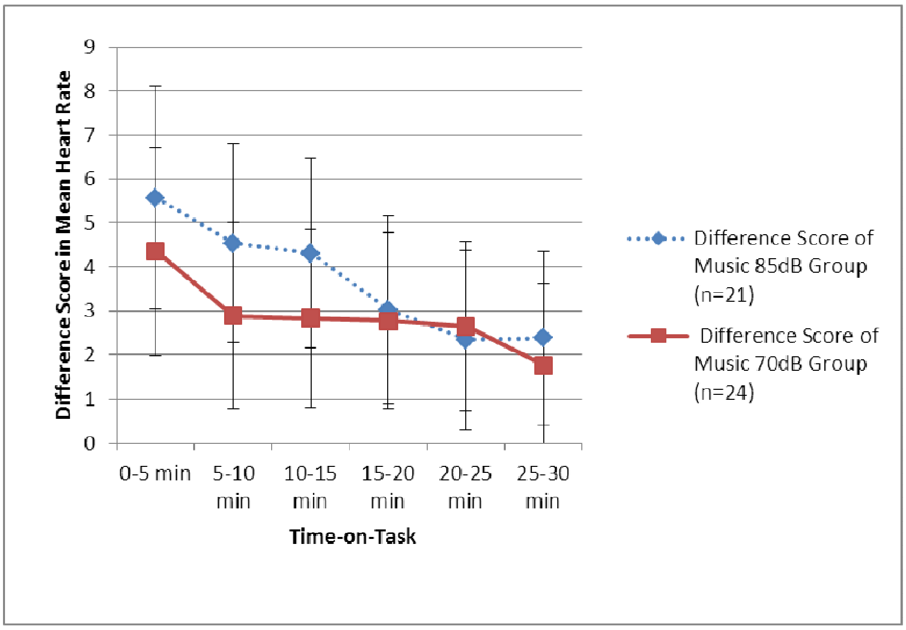

Figure 5. Difference scores between mean heart rate while driving with and without music. Bars represent the standard errors for the difference scores.

3.4. The effect of music on heart rate variability

Prior to examining whether music would lead to decreased heart rate variability (in the mid, 0.10 Hz frequency band) reflecting increased mental effort, we again explored the sensitivity of the heart-rate measures by examining whether the driving task-induced heart rate variability differed from the baseline heart rate variability measurements taken before and after each drive (Resting 1 and Resting 2 for each condition). An overall mixed-model ANOVA with the resting and driving task-induced heart rate variability scores for the music and no-music conditions revealed a main effect of driving on heart rate variability (F(5,210)=12.34, p< .001, η_p^2= 0.23). Repeated contrasts revealed that heart rate variability during driving without music (M= 6.9, SD= 0.66) was significantly lower than heart rate variability during Resting 2 (M= 7.6, SD= 0.68; F(1,42)= 50.68, p< .001), but not significantly different from Resting 1 (M= 7.0, SD= 0.96; F(1,42)= 2.90, p< .10). Contrasts further revealed that mental effort was higher while driving with music, as heart rate variability during the drive (M= 6.9, SD= 0.62) was significantly lower than heart rate variability during Resting 1 (M= 7.2, SD= 0.94; $F(1,42)$= 6.98, p< .05) and Resting 2 (M= 7.4, SD= 0.87; $F(1,42)$= 23.43, p< .001). These findings suggested that heart-rate variability was sensitive to driving task characteristics and the presence of music accompanying the task.

Next, we compared the heart rate variability of the participants during 30-min task periods in the conditions with music and without music. A mixed-ANOVA revealed no significant differences in heart rate variability while driving with music (M= 6.90, SD= 0.62) and while driving without music (M= 6.89, SD= 0.68; F < 1, *ns*). Inspection of the heart rate variability of the participants during each of the 5-min intervals with music and without music revealed a similar finding, and as opposed to our expectations, results revealed no main effect of the presence of music on heart rate variability (see Table 1). There was no main effect of group on heart rate variability, and no interaction of group and the presence of music either.

4. Discussion

In the current study, the influence of music on driving performance in monotonous and low-complexity driving conditions was examined. We first hypothesized that listening to music would either have no effects or a positive effect on performance in a car-following task (Hypothesis 1). Second, we hypothesized that arousal level of the participants would be higher when the driving task was accompanied by music as compared to when it is not accompanied by music (Hypothesis 2a). We further hypothesized that the expected influence of music on arousal would be more pronounced in a condition with loud volume music than moderate volume music (Hypothesis 2b). Third, we hypothesized that mental effort inferred from heart-rate variability would be higher in the absence of music than in the presence of music (Hypothesis 3).

Our first hypothesis on no effects or a positive effect of music on driving performance in monotonous settings was supported, and listening to music did not impair performance in a car-following task as indicated by a variety of measures.

First, drivers performed equally well while driving with music and without music as reflected by the coherence of their driving, i.e., how well speed changes of a lead car were followed. This finding is in line with earlier studies on the effects using a mobile-phone on coherence (De Waard & Brookhuis, 1991; Brookhuis et al., 1994), and demonstrates that in monotonous situations drivers are able to carry out a car-following task accurately despite the presence of a secondary task, in our case listening to music, and irrespective of the volume of music. Second, and importantly, the findings on the main indicator, namely delay in responses to the speed changes of the lead vehicle, revealed that listening to music even improved some aspects of driving performance, irrespective of the volume level. More specifically, drivers responded to the lead vehicle faster when they listened to music as compared to when there was no music, and this pattern was consistent over time as there were no time-on-task effects for delay. This finding is in line with earlier findings on lowered response latencies in a shorter car-following task (Ünal et al., 2012), and therefore, confirmed that regardless of the length of the car-following task, music improved responses to speed changes of the lead vehicle.

Third, we found that drivers' lateral control was relatively better in the presence than in the absence of music, as indicated by a somewhat smaller SDLP during the last 20 minutes of car-following while listening to music, irrespective of the volume. The slight increase in SDLP during the last 20 minutes of car-following in the absence of music might seem small, yet is not negligible as it is in line with the existing criteria for impaired SDLP provided by previous literature (see Brookhuis, de Waard & Fairclough, 2003). Interestingly, during the first 10 minutes of car-following no such difference was observed in lateral control between conditions with and without music. Previous research has documented that using a mobile phone while car-following had no or even positive effects on car-control performance (Lamble et al., 1999; Alm & Nilsson, 1995; Brookhuis, et al., 1991). The present result extends the findings of this literature by showing that listening to music does not impair lateral control during car-following either Therefore, the results lend further support to the argument that some aspects of performance might benefit from the presence of secondary tasks or distracters in monotonous driving tasks (Heslop et al., 2010). We should note, however, the pattern of findings on delay scores were not consistent with the literature on using mobile-phones during car-following. While using a mobile phone was associated with impairment in response latencies to the speed changes of the lead vehicle (Lamble et al., 1999; Alm & Nilsson, 1995), listening to music improved response latencies. This suggests that not all secondary tasks may influence driving performance similarly in monotonous tasks. Indeed, our finding on the improved responses to the lead vehicle in the presence of music indicates that listening to music might somehow work differently to affect performance in monotonous tasks compared to other secondary tasks. For instance, the listening component of a mobile phone task might be more engaging as compared to listening to music or the radio (Strayer & Johnston, 2001), which might explain the findings on impaired response times with the use of mobile phones.

In the current research, we were mainly interested in arousal as a relevant process variable that could explain the observed no-effects or positive effects of music on performance in monotonous driving tasks. Specifically, we proposed music would lead to increased arousal (Hypothesis 2a), and therefore, provide drivers with external stimulation while busy with monotonous driving tasks. Our findings on both the self-reported and physiological indicators of arousal indicated that listening to music indeed increased the arousal level of the participants. Specifically, self-reports of drivers suggested that drivers were more aroused when there was music accompanying the driving task as compared to driving without music. A similar pattern was evident from the physiological indicator of arousal, namely mean heart rate, which was higher while driving with music compared to driving without music, particularly in the first part of the simulated drive. So, Hypothesis 2a on increases in arousal when driving with music was supported. When interpreted together with the findings on performing better in the presence of music, the results suggest that drivers were more attentive when they were more aroused due to listening to music while driving. As such, our study gave support to the predictions based on Easterbrook's (1959) cue-utilization theory that increases in arousal would facilitate the processing of relevant cues in tasks that require continuous attention.

Interestingly, the inspection of time-on-task effects revealed that the differences observed in mean heart rate when driving with music versus without music were more pronounced for the first 20 minutes of a 30 minute drive, suggesting a habituation effect. So, participants seemed to accommodate to the arousing effect of music close to the end of the drive. Together, the findings showed that music is indeed a powerful source of arousal (Fontaine & Schwalm, 1979; McNamara & Ballard, 1999), while however, in instances of driving for longer periods in monotonous conditions, the arousing effects of music might also diminish over time.

Apart from investigating the influence of music on arousal in general, we also aimed to explore whether loud volume music would increase arousal more than moderate volume music does (Hypothesis 2b). As opposed to our expectations, arousal as reflected in mean heart rate was not influenced differently by the volume of the music. There was a trend for loud volume music to increase self-reported arousal though, as compared to moderate volume music, but this trend did not reach statistical significance. In addition, there was no difference between the driving performances of people who listened to music with either loud or moderate volumes. So, the findings indicate that regardless of the volume level, listening to music as such was the main reason for a higher arousal and a better performance attainment while following a lead vehicle.

As an increased level of arousal was expected to ease task-demands while driving in monotonous conditions, we predicted that mental effort inferred from heart-rate variability would be higher in the absence of music than in the presence of music (Hypothesis 3). The findings did not support this hypothesis. More specifically, mental effort that was tracked by the changes in heart rate variability was not lower while driving with music than without music. Research suggested increases in self-reported mental effort and workload with the presence of music while busy with not only demanding driving tasks consisting of hazardous incidents (Ünal et al., 2012, Hughes et al., 2013), but also while busy with short monotonous driving tasks (Ünal et al., 2012). Therefore, the current finding of no-differences in mental effort supports earlier findings that heart-rate variability might not be a sensitive measure in detecting changes in state-related mental effort that is expected to increase in monotonous conditions (see L. Mulder, De Waard, & Brookhuis, 2005). An alternative explanation is that the expected relationship between increases in state-related effort in the absence of external stimulation might be observed only when the performer is busy with the same monotonous tasks for even longer periods. Maybe then, the decrease in arousal due to habituation effect would lead to increases in mental effort in the expected direction.

5. Limitations and Future Research

The current research had some limitations. First, although driving simulators are being commonly used in traffic research due to their practicality and high level of experimental control, replications of the study in real-life driving settings, such as via on-road assessments involving monotonous driving tasks, are needed in order to ensure the generalizability of the findings. Second, in the current study, we aimed at a high ecological validity in terms of the music stimuli, and therefore, made participants chose their own music. As a consequence, we did not have control over the structural properties of music (e.g. tempo, mode, rhythm). Future research might examine whether the effects of music on driving performance, arousal and mental effort in monotonous settings depends on structural properties of the music presented to participants.

Third, although listening to music with loud or moderate volume did not influence the vast majority of our main variables differently, we observed an unexpected group difference in terms of some aspects of car-following performance. In particular, irrespective of the presence and absence of music, one group of participants (who were in the loud-volume music group) performed better in terms of coherence of driving and delay of response to changes in driving of the lead car, suggesting they outperformed the other group in the car-following task. Participants were randomly assigned to the experimental groups, which is a strong and preferred method (c.f. Pelham & Blanton, 2007) as matching groups on every possible factor of influence is not feasible. In the current study, randomization indeed seemed to work well, as there were no differences between the groups in terms of driving experience, age, and gender distributions. Therefore, the current finding is surprising. We suspect that the observed group differences might have resulted from some other uncontrolled driver or personality characteristics, such as sensation-seeking or extraversion. For instance, research indicated that high and low sensation-seekers have different preferences for optimal level of arousal (Litle & Zuckerman, 1986), meaning that monotonous driving conditions or the presence of music in such conditions might affect them differently. Therefore, future research could also take into account the possible interaction of personality factors with arousal while studying driving performance in monotonous conditions. Furthermore, our study employed young drivers who might tolerate loud volume music better than elderly drivers. Future studies may also target employing an older group of drivers in order to explore whether our results can be replicated in different samples.

Finally, the current study was the first attempt to investigate the relationship between music-listening and mental effort during a low-complexity monotonous drive. Yet, our findings did not confirm the expectation that mental effort would be lower in the presence than absence of music. Future research is needed to further explore the relationship between music and mental effort in prolonged monotonous and low-complexity traffic settings, as well as to identify the extent to which the observed finding was an artefact of the measure used for assessing mental effort (i.e., heart rate variability).

6. Conclusions

The current study aimed to explore how music affects driving performance in monotonous driving situations marked by low-complexity. Our findings revealed that listening to music does not impair performance in a car-following task. Rather, we found that music did not inhibit performance and even positively affected some aspects of performance. In addition, we showed that music increased arousal while driving. Importantly, although loud-volume music had a higher potential to activate individuals as compared to moderate-volume music, the volume of music did not influence car-following performance differently. Together with the findings on maintained and sometimes even improved driving performance, the pattern of results support the argument that irrespective of the volume level of music, music provides drivers with some additional external stimulation that might be useful to stay vigilant while executing monotonous driving tasks in low-complexity traffic settings.

Our findings suggest that the presence of music might benefit driving safety in low-complexity and monotonous driving conditions. For instance, although not tested in the current study, it is possible that drivers might engage in some risky actions on monotonous roads, such as speeding or close-following, in order to satisfy their need for arousal. Our findings suggest that when busy with monotonous driving tasks listening to music might be a good strategy to counter boredom and to satisfy the need for arousal. Future studies could explicitly focus on potential safety effects of listening to music during longer journeys.

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Chapter 5

General Discussion

In the current thesis, we investigated the influence of listening to music or the radio on driving performance. In addition, we examined via which processes music or the radio influences driving performance. Importantly, we assumed that the context where music or the radio-listening takes place is crucial in predicting how individuals would be influenced by music (Scherer & Zentner, 2001). Therefore, we investigated the effects of listening to music and the radio both in high and low-complexity traffic environments, which are the two relevant contexts that drivers are normally exposed to. Unlike previous research (Brodsky, 2002; Pêcher et al., 2009; North & Hargreaves, 1999), we systematically manipulated task-characteristics (such as abundance or absence of critical incidents) rather than music-characteristics in high and low-complexity traffic settings. This approach allowed us to study whether demands induced by the driving task itself (rather than music) would be more predictive for understanding to what extent and how drivers would be influenced by music while driving.

In previous investigations on the influence of music and radio-listening on driving, scholars argued that music and the radio is distracting for drivers and therefore, might inhibit driving performance (Brodsky, 2002; Pêcher et al., 2009). Yet, indications for an actual impairment in driving performance while listening to music or the radio were scarce (Brodsky, 2002; Pêcher et al., 2009). In addition, it was commonly reported that music or the radio was found to have either no-effects on performance (Turner et al., 1996; Strayer & Johnston, 2001; Van der Zwaag et al., 2012) or positive effects (Fontaine & Schwalm, 1979; Turner et al., 1996; Hughes et al, 2013; Beh & Hirst, 1999), while however, understanding the processes behind such positive effects or no-effects were missing. Based on those findings depicting non-negative effects in relation to music or radio-listening while driving, we expected no impairment in driving performance in the current studies as well. Yet, we also investigated the processes via which music and the radio would have no-effects or a positive effect on driving performance. Particularly, we reasoned that music or the radio would not inhibit performance in high-complexity traffic settings because drivers would use compensatory strategies to cope with the distraction induced by music or the radio in such contexts. We expected that music or radio would not inhibit performance in low-complexity settings either, while however, due to a different process than compensatory strategies, namely arousal. So, we expected that music induced arousal might actually benefit driving performance in very low-complexity traffic settings by means of providing drivers with an external stimulation that is needed in monotonous driving conditions.

Specifically, we reasoned that in high-complexity traffic drivers would prioritize the driving task while listening to music or the radio in order not to compromise driving safety. But what are the mechanisms behind this task-prioritization? According to the compensatory control model of Hockey (1997), a common strategy used by individuals to prioritize the primary task over secondary tasks or distracters is to regulate mental effort. So, when distracters or secondary tasks compete for the shared cognitive resources needed by the primary task, individuals might resist distraction (Kahneman, 1973) by means of investing more effort on the main task at the cognitive level. Additionally, Kahneman (1970) argued that individuals might also resist distraction by means of regulation of attentional resources. For instance, when the primary task of driving is accompanied by a secondary task, regulation of attention might help drivers to focus on the aspects that are important for primary task-performance. As a result, the secondary task might receive less attention, and therefore be ignored to some extent in order to secure performance on the main task. Based on the theoretical framework proposed by Hockey (1997) and Kahneman (1970), we expected that drivers would both regulate their mental effort and regulate their attentional resources when driving in high-complexity traffic which is marked by heavy traffic and abundance of risky incidents. We expected that in such contexts, prioritization of the main task of driving becomes particularly important in order to negotiate the risky driving situations safely and to decrease accident likelihood. Therefore, in Chapter 2 and 3 of this thesis, we investigated regulation of mental effort and regulation of attentional resources as relevant processes that might explain how driving performance is maintained while listening to music or the radio in high-complexity traffic settings.

Driving also involves situations where drivers have to execute monotonous tasks in traffic environments that are very low in complexity. In such environments, drivers might suffer from under-arousal due to the absence of external stimulation, and they might experience negative states like boredom or fatigue. As a result, the driving task could be demanding and effortful, and might also lead to having higher mental workload. Importantly, as predicted by the Yerkes-Dodson law (1908), a state of low arousal is expected to impair performance by inhibiting attentional processes (Easterbrook, 1959). Therefore, an optimal level of arousal would help to maintain performance when busy with monotonous tasks. In addition, it was suggested that for monotonous or very easy tasks need for more arousal would be much higher than for complex tasks, meaning that moderate to high external stimulation might help individuals to perform better (McGrath, 1963). In line with these assumptions, we expected that music might provide drivers with the optimal level of arousal needed to perform well on the driving task in very low-complexity traffic settings. So, we assumed that in low-complexity situations (i.e., a monotonous driving task), driving performance would be maintained through arousal induced by listening to music rather than by the employment of the cognitive strategies used in high-complexity situations (Chapter 4). Below, we will discuss the main findings of each chapter, and next elaborate on the theoretical and practical implications of the findings.

Chapter 2: Does music affect mental effort and driving performance in high-complexity traffic?

In Chapter 2 of this thesis, we investigated how and to what extent music influences driving performance while driving in a rather complex traffic environment with an abundance of critical incidents (e.g. parked car driving off from a parking lot). We reasoned that when traffic complexity is high, drivers would make use of compensatory strategies to maintain their driving performance while listening to music. Based on Hockey's compensatory control model (1997), we hypothesized that increases in mental effort in the presence of music would be an indication of task-prioritization while driving in high-complexity traffic settings. So, we expected that mental effort of drivers who listened to music would be higher than the mental effort of drivers who did not listen to music. Importantly, we hypothesized that the strategy of regulation of mental effort would help drivers who listen to music to perform as well as or sometimes even better than drivers who did not listen to music. We also hypothesized that any performance improvement with the presence of music would result from increases in mental effort experienced while listening to music, meaning that mental effort might mediate the effect of music on driving performance.

In a hazard-dominant simulated driving experiment, we found that drivers who listened to music while driving indeed reported higher mental effort as compared to drivers who did not listen to music, irrespective of the complexity of driving incidents. That is, in all situations, drivers reported higher mental effort when driving with music as compared to drivers who did not listen to music. These findings suggest that the amount of increase in mental effort seems to be constant across driving incidents, and is elicited by the extra load induced by music-listening in the first place. So, in line with our expectations, the finding gave support to Hockey's compensatory control model (1997), and indicated that drivers prioritize the driving task when an additional stimulus (i.e. music) adds on the already existing task-demands in complex driving situations. In other recent investigations, scholars found no effect of music on mental effort in a short driving task (6 lapses on a 1.1km road) or in a driving task that included driving on narrow lanes which was supposed to be demanding (Hughes et al., 2013; Van der Zwaag, 2012). In our study, we used a relatively longer route to drive (i.e., 30 min long) and increased driving task demands by manipulating the traffic complexity. So, based on our findings, we conclude that music might necessitate the regulation of mental effort especially in situations where task-demands are already relatively high due to the complexity of the traffic setting. Then, does regulation of mental effort help drivers to secure their driving performance while listening to music in high-complexity traffic?

We used several performance indicators (e.g. brake time, accepted gap time, and time-to-contact) to observe changes in driving performance while listening to music, most of which reflected performance during critical incidents. We found that drivers who listened to music performed as good as the drivers who did not listen to music on the majority of performance indicators. This shows that regulation of mental effort was indeed an effective strategy to handle the cognitive load induced by music. Interestingly, drivers who listened to music performed even better than drivers who did not listen to music in two of the critical incidents, namely a parked car suddenly leaving a parking lot and car-following. For instance, regarding the former incident, we found that drivers who listened to music braked earlier to avoid a crash with the parked car. For the latter incident, we found that music listeners followed the lead car better as compared to drivers who did not listen to music. Did the improved performance result from a heightened mental effort among drivers who listened to music? To answer this question, we conducted mediation analyses, and found that mental effort mediated the effect of music on driving performance only for one of the indicators of the car-following task. Overall, our findings indicate that the regulation of mental effort can be a useful strategy to maintain performance at a desired state, while at the same time; performance can be maintained or improved by other processes as well. In Chapter 3, we tested another process that might be relevant for performance under conditions of multitasking, such as listening to music or the radio while driving, namely regulation of attentional resources.

Chapter 3: Do drivers block-out radio-content when driving and especially when driving in a high-complexity traffic setting?

Kahneman (1970) argued that individuals might also prioritize tasks by means of regulation of attentional resources. It has been suggested that attentional resources might be allocated on tasks in such a way that important tasks receive more attention while less important secondary tasks receive less attention and can even be ignored. As a result, one might observe performance decrements on the secondary task in order to secure performance on the main task (Hockey, 1997). Based on Kahneman's (1970) conceptualization, we reasoned that drivers are likely to prioritize the driving task by regulating their attention while listening to music or the radio. Specifically, we expected that drivers would regulate their resources in such a way that the secondary task of radio-listening would receive less attention, especially in a drive with high-complexity traffic. We called this process of allocating less attention on the radio as blocking-out radio-content, which we measured by calculating the amount of content that would not be recalled properly after the trip.

We reasoned that the inclination to block out the radio should depend on demands induced by the driving task. So, we hypothesized that the amount of blocked-out radio content would be higher in the presence of the main task of driving as compared to when not busy with driving. We further expected that the amount of blocked-out radio content would be higher while driving in high-complexity traffic (i.e., 13 critical incidents) as compared to while driving in a relatively low- complexity traffic environment (i.e., 2 critical incidents), as the former is expected to be more demanding for drivers. Importantly, we hypothesized that blocking-out is an efficient way to secure driving performance. Consequently, we expected that drivers who listened to the radio would perform as well as drivers who did not listen to the radio, irrespective of the complexity of traffic.

The findings revealed that drivers who listened to the radio indeed performed as well as the drivers who did not listen to the radio. So, in line with the previous literature, drivers who listened to the radio were able to maintain their driving performance (Hatfield & Chamberlain, 2008; Strayer & Johnston, 2001). Next, we explored whether the maintained driving performance might be related to blocking-out radio content, which would reflect that drivers prioritize the driving task over the secondary task of radio-listening. As expected, we found that radio-content was blocked-out more when it was accompanied by the driving task as compared to when there was no driving task, irrespective of the specific radio content (i.e. music, commercials, and talk-radio excerpts). This indicates that demands coming along with driving might lead people to block-out radio content as to be able to secure driving performance.

To investigate whether an increase in driving task-demands would create the urge to prioritize the driving task even further, we compared the amount of blocked-out audio contents in high-complexity and relatively low-complexity traffic situations. The findings revealed that drivers did indeed block-out talk-radio excerpts more while driving in high-complexity traffic than in relatively low-complexity traffic. For the other two types of radio content, namely music excerpts and commercials, there was no difference in the amount of blocked-out content in high and relatively low-complexity traffic. So, the findings related to blocking-out of music and commercial excerpts did not support our expectation that high-complexity traffic setting would lead to more blocking out of radio content. We reasoned that retrieving music excerpts by naming the title of the song or name of the performer may have been a difficult task in the first place, and that music excerpts can probably be more easily remembered when asked to retrieve a melody rather than song or band names (Levetin & Cook, 1996), which might partially explain the above-mentioned no differences in blocking-out music in high and relatively low complexity traffic. As for commercials, research showed that commercials were the main reason for drivers to switch between radio-stations (McDowell & Dick, 2003), indicating that drivers try to avoid being exposed to commercials when they can do so. In our case, drivers did not have such control, but they might have avoided paying careful attention to commercials anyway, irrespective of the complexity of the traffic situation. Still, our findings showing that talk-radio excerpts were blocked out more during a high-complexity drive than a low-complexity drive indicated that drivers were more likely to engage in task-prioritization when driving in high-complexity traffic.

In general, the findings of Chapter 3 gave support to our expectation that the driving task would be prioritized over the secondary task of radio-listening. This was particularly apparent by the findings showing that radio-content is being blocked out more while driving as compared to while solely listening to the radio, and by the finding blocking out talk-radio excerpts to a higher extent in high-complexity than in relatively low-complexity traffic settings. These findings are in line with research on other types of secondary tasks conducted while driving, such as talking to passengers, which also showed that performance on a secondary task is likely to impair to preserve primary task performance (Maciej et al., 2011; Drews et al., 2008; Crundal et al., 2005, Cnossen et al., 2004). Therefore, the current finding extended the literature by showing that an impairment similar to the one found for secondary task performance applies to the additional task of radio-listening. Apparently radio can be demanding to listen to while driving, but drivers seem to be good at handling the additional demands. Importantly, previous investigations regarding radio-listening (Hatfield & Chamberlain, 2008; Strayer & Johnston, 2001) did not provide an explanation regarding how performance is maintained despite the presence of an additional auditory task. With the current findings, we were able to show that performance can be maintained via blocking out audio content.

In Chapter 4, we investigated the outcomes of listening to music in a monotonous traffic environment that is extremely low in traffic complexity.

Chapter 4: Does music influence arousal and driving performance in low-complexity traffic settings?

Chapter 2 and 3 studied the effects of music and radio listening in traffic settings with high and relatively low complexity, and found that drivers preserve their driving performance by employing cognitive compensatory strategies to prioritize the driving task while listening to music and the radio. But what will happen in extremely low-complexity traffic setting, where demands are too low rather than too high? To what extent and how will listening to music or the radio affect driving performance in such settings? In Chapter 4, we addressed these questions, and focused on the influence of music on driving performance in very low-complexity traffic settings when busy with a monotonous driving task.

Low-complexity traffic settings reflect those road conditions in which drivers rarely come across to other road-users, and where the road environment is rather dull and unchanging. So, in very low-complexity settings, the driving task is executed in a highly predictable and monotonous environment (Wertheim, 1991). In such environments, drivers are expected to suffer from low-arousal due to under-stimulation, and consequently from boredom or drowsiness which might make them prone to accident involvement by impairing attentional processes (Nelson, 1997; Thiffault & Bergeron, 2003). As such, low-complexity traffic settings might also be demanding to manage, as drivers need to force themselves to stay awake and vigilant.

We reasoned that listening to music or the radio would help drivers to stay vigilant in such contexts, by means of increasing arousal closer to optimal.

The study was again conducted in a driving simulator. However, the simulated world was different than the ones adopted in Chapter 2 and 3 in several important ways. First, there were no hazardous incidents posing any danger while driving. Second, drivers were exposed to the same unchanging road environment the whole time, which was high in predictability. Third, drivers had to execute a monotonous driving task, namely car-following, for half-an-hour. They were not allowed to overtake the lead vehicle or explore other routes in the simulated world, but simply had to drive straight ahead behind the lead vehicle. As such, we aimed at creating conditions of extreme monotony and hence very low complexity, in an attempt to understand the processes behind performance maintenance in such situations.

Similar to the expectations regarding driving performance in the first two studies that focused on high complexity situations, we hypothesized that listening to music would not impair performance in a monotonous car-following task. Importantly, we expected that music would affect driving performance in very low-complexity traffic settings via a different process: music would bring arousal to a more optimal level. That is, based on Yerkes-Dodson (1908) law, which predicts performance increments only when individuals are moderately aroused (and not when the arousal level was too high or too low), we expected that drivers would perform better when they were somewhat aroused than when they had lower arousal. It has been argued that arousal depends on the complexity of tasks, and that individuals might have a need for higher arousal when engaged in rather low-complexity tasks (McGrath, 1963). Since both the car-following task and the road conditions were relatively predictable in the current study, the driving task was not difficult to execute and low in complexity, meaning that drivers could have a higher need for arousal during the drive. Hence, we assumed that the optimal level of arousal induced by music should also be high during the car-following task in order to enhance driving performance. To further test this assumption, we employed two volume levels, namely loud volume and moderate volume, which were thought to induce high and moderate levels of arousal. In addition to studying arousal in low-complexity situations, we also explored mental effort in low complexity situations with and without music. We expected that in low-complexity settings, drivers would report a higher (rather than lower) mental effort in the absence (rather than presence) of music while executing the car-following task. That is, we reasoned that driving in a monotonous environment would be cognitively more demanding when there was the lack of external stimulation (in this case music). So, we expected that mental effort would be higher in the absence of music and when busy with a monotonous driving task in a low-complexity environment, in order to stay vigilant.

In line with our expectations, we found that listening to music did not impair car-following performance. In fact, some aspects of driving performance were even found to improve in the presence of music. For instance, in the presence of music drivers were found to follow the lead car with less delay, and therefore more promptly than in the absence of music. Also, music appeared to improve lane-keeping performance, which is in line with earlier studies that also showed facilitated lane-keeping in the presence of secondary tasks, such as talking on mobile phones, during monotonous driving tasks (Lamble, Kauranen, Laasko, & Summala, 1999; Alm & Nilsson, 1995; Brookhuis, et al., 1991). So, these findings supported our expectations that music might facilitate car-following performance by providing drivers with external stimulation in low-complexity traffic settings.

Inspection of arousal levels of drivers revealed that music lead to an increment in arousal, as measured by heart-rate recordings. Interestingly, while there was a trend for loud volume music to lead to higher arousal than moderate volume music, this trend did not reach significance. Hence, there was no difference in arousal levels of participants who listened to loud or moderate volume music. This suggests that both types of music were equally arousing. In addition, we did not find support for the hypothesis that mental effort would be higher when driving without (rather than with) music. Previous studies suggested that in monotonous and non-stimulating driving situations drivers might experience adverse states, such as boredom and drowsiness, which might result in higher mental effort that would help drivers to stay vigilant (Warm, Parasuraman, & Matthews, 2008; Warm, Dember, & Hancock, 1996). Apparently, the car-following task used in the current study did not lead to such extreme adverse states, meaning that such effects are more likely to show up in prolonged monotonous driving conditions. Yet, this study was the first to examine the influence of music on driving performance in a continuously monotonous environment, and indicated that drivers might make use of listening to music while busy with monotonous tasks in low-complexity environments, as music brings arousal to a more optimal level and helps drivers to stay focused.

Implications

In previous investigations on the effects of music on driving, the context of music listening while driving has mostly been ignored. We argued that the driving context has an important effect on whether and how music and radio listening affects driving performance, and how driving performance is maintained when driving and listening to music or the radio. Therefore, in contrast to previous studies, we explicitly manipulated traffic complexity to study the differential effects of music and radio-listening in different traffic environments. In three empirical chapters, we investigated the influence of music and the radio on driving performance, and via which processes driving performance is maintained. Together, the chapters indicated both the influence of music and the processes via which performance is secured depends largely on traffic complexity and the demands induced by the driving task itself. The current thesis, therefore, provides valuable insights for theory and practice by differentiating between the effects of music on driving performance in different driving contexts.

In high-complexity traffic

Chapter 2 and 3 of this thesis focused on how and to what extent music or the radio influences driving performance in high-complexity traffic. Our findings gave support to predictions based on the Hockey's (1997) compensatory control model and Kahneman's (1970) theory of attention-control that both stipulate that individuals prioritize main tasks over secondary tasks by adopting cognitive strategies. Specifically, Chapter 2 of this thesis suggests that when the driving task takes place in a rather complex traffic environment, mental effort of drivers who listen to music is somewhat higher than mental effort of drivers who do not listen to music. This finding indicates that listening to music might be cognitively demanding when there is an abundance of critical incidents which increase accident likelihood, and therefore creates the need to put more effort on the main task. By increasing their mental effort drivers are trying harder to maintain their driving performance at the desired level, meaning that driving task is prioritized over additional tasks. Chapter 3, which also included a high-complexity driving condition, further indicates that drivers might be prioritizing the driving task by blocking-out audio stimuli, both in high and relatively low complexity traffic settings. So, when the audio-stimuli induce cognitive demands and compete for the limited cognitive resources needed for the safe execution of the driving task, drivers regulate their attentional resources such that they focus less on the secondary task. Together, the findings provide initial evidence for the adoption of several strategies when listening to music or the radio in order not to compromise driving safety while driving, and especially while driving in a rather complex environment. The good news for traffic safety is that drivers seem to cope well with the demands induced by music and radio-listening even in highly demanding traffic conditions.

The type of traffic setting used in Chapter 2 and partly in Chapter 3, which we define as high-complexity traffic, resemble traffic conditions in areas where drivers share the road with many other road users. Since no impairment in driving performance was documented in the current studies, the findings suggest that employing cognitive compensations are efficient coping strategies while driving in such areas. So our findings lend support to the notion that driving task is assigned a higher importance and drivers generally target driving safety as their main goal on the road (cf. Dogan, Steg, & Delhomme 2012).

In low-complexity traffic

Chapter 4 of this thesis focused on how and to what extent music or the radio influences driving performance in a very low-complexity traffic setting. The findings indicated that listening to music leads to increments in arousal, irrespective of the volume of music. In line with our expectations, listening to music did not impair driving performance during car-following, and lead to even improved performance in some aspects of driving. Together, the findings suggest that music influences driving performance via a different process in monotonous and low-complexity traffic settings than in higher-complexity settings, namely through arousal. Interestingly, music seemed to have no influence on mental effort in monotonous driving conditions, suggesting that different than observed in high-complexity traffic, music is not more cognitively demanding in low-complexity traffic. Importantly, the volume of music being loud or moderate also did not make a significant difference in terms of the experienced mental effort, suggesting that even a more demanding type of music (i.e. loud) is tolerated well and does not act as a distracter in low-complexity settings. That is apparent by looking at the car-following performance which was not affected by the volume of music. Previous investigations indicated that for tasks that are not complex to execute (such as highly predictable tasks), need for arousal is higher (McGrath, 1963), meaning that a more arousing stimulus can benefit performance more. As we did not find any difference in terms of the arousing potentials of high and moderate volume music, we found no empirical support for McGrath's (1963) predictions, meaning that loud music did not increase arousal to an even more optimal level. However, the findings of Chapter 4 in relation to arousal suggested that even loud music, which was shown to be highly arousing and even more demanding to listen to (North & Hargreaves, 1999), did not impair driving performance in monotonous conditions.

Chapter 4 demonstrates that the presence of music is better for driving performance than the absence of music in very low-complexity settings. Importantly, music seemed to satisfy the need for arousal in low-complexity settings, as some aspects of car-following performance even improved, indicating that drivers were more vigilant while listening to music. Although not tested in the current study, it is possible that drivers would look for other ways to satisfy their need for arousal in the absence of music, such as by increasing their speed or close following. These kind of risky behaviors might work well to increase arousal, but at the expense of a higher accident likelihood. So, we believe that the current findings are highly relevant in promoting traffic safety especially among those drivers who are exposed to monotonous traffic settings for the majority of time. Based on our findings, we conclude that listening to music can be a good strategy to counter boredom or fatigue in very low-complexity traffic settings. Therefore, we suggest that interventions targeting monotonous driving conditions might promote music-listening when drivers are experiencing adverse driver states as to increase arousal closer to optimal. A major contribution of the current studies to the literature on music and driving is the emphasis given to task-characteristics rather than music characteristics. Whereas previous studies tried to increase task demands by manipulating music-related characteristics (e.g. tempo, volume; North & Hargreaves, 1999; Brodsky. 2002), we aimed at increasing demands by manipulating task characteristics. The current studies showed that task-characteristics are indeed predictive of which processes come into play while driving and listening to music or the radio. When demands are high due to traffic complexity, the presence of music or the radio leads to employing compensatory strategies to prioritize the main task (i.e., driving; Chapter 2 and 3). However, no such strategies are employed when driving in an extremely low-complexity traffic setting. Rather, in such settings, music influences performance by facilitating vigilance through arousal, and therefore, benefits driving performance (Chapter 4).

In the studies reported in the present thesis, music characteristics as such did not predict how drivers would be influenced by music-listening. Both Chapter 2 and Chapter 4 included loud volume music (~ 85dB), which was suggested to be more demanding to listen to (North & Hargreaves, 1999). However, we did not find any performance decrements in neither of the studies, meaning that even a supposedly demanding type of music can be tolerated to some extent by drivers. Loud music led to increases in mental effort in Chapter 2 as an indication of task prioritization in a highly-complex traffic setting, while no such increment in mental effort was observed while driving in a very low complexity traffic setting (i.e. Chapter 4). Thus, as we reasoned, a demanding type of music seems to increase task-demands only when the driving demands are already high due to task-related factors such as traffic complexity. So, driving task demands are prior in predicting whether compensatory actions or strategies would be employed in response to additional stimulus such as music.

Previously listening to music has been suggested to increase the frequency of violations on the road, especially in the case of some specific types of music such as high-tempo music (Brodsky, 2002). In addition, it has been suggested that drivers might benefit from listening to particular types of music that hypothetically induce lower listening demands (e.g. instrumental, moderate tempo, unfamiliar; see Brodsky & Kizner, 2012). The findings of the current thesis (Chapter 2, 3 and 4) do not support the expectation that music might contribute to violation or accident likelihood. In all three chapters, participants listened to songs that they were familiar with. In addition, in Chapter 2 and Chapter 4, we used loud music to create a more demanding listening situation. Yet, we consistently found that drivers were able to prioritize the driving task and traffic safety, and driving performance was not reduced. As such, our findings do not support the expectation that drivers might benefit from playlists that are easy to listen to. We believe that more research is needed to address the inconclusive findings in the literature. Importantly, replications are needed in order to reach firmer conclusions on possible practical implications of not only our findings but also findings of the previous literature.

Limitations and Suggestions for Future Research

The work of the current thesis provided valuable insights in terms of how music and radio-listening influence driving performance in traffic environments varying in complexity. Yet, there are still some points that should be targeted by future research in order to enhance our understanding of how music and radio are being handled while driving.

First, the current studies did not show any impairment in driving performance in the presence of music or the radio, and we argued that this was due to employing cognitive compensatory strategies in high-complexity settings, and increases in arousal in very low-complexity traffic settings. In all three studies, we employed simulated studies that last approximately 30 minutes. So, it is of interest to find out whether our results on no impairment in driving performance can be replicated in longer (simulated) driving studies or in studies consisting of on-road assessments of driving performance.

Second, in the current research we largely focused on relatively high and low-complexity traffic settings in an attempt to establish whether music or radio-listening would trigger different processes in such different settings. Yet, as high and low complexity settings are representative of rather extreme conditions, it would be of interest to find out how music and the radio influence driving performance in less extreme conditions, such as in environments with moderate levels of complexity.

Third, in the current studies we employed a young sample of drivers. Young drivers might have been used to listen to music while driving, and therefore might be tolerating the demands induced by music better than older or elderly drivers. Hence, future studies should try to replicate these findings in other samples of the population. More generally, we did not test whether individual differences would mediate the influence of music or the radio on driving performance. One relevant individual difference factor might be driving experience. Our sample consisted of drivers with low to moderate levels driving experience who can neither be classified as novice nor as experienced drivers. As driving experience might affect the way people employ compensatory strategies, for novice drivers it might be more difficult to drive along in the presence of music or the radio, as their ability to regulate cognitive resources based on the importance of tasks might not be fully developed. In addition, learner and novice drivers have been consistently shown to have poor hazard perception abilities, characterized by lack of anticipation of hazardous events leading to detection and response latencies (see Vlakveld, 2011; McKenna & Crick, 1997; Sexton, 2001). Hence, future research is needed to examine whether music or radio-listening would further interfere with the hazard perception abilities of novice/learner drivers. Apart from driving experience, some personality factors might also affect the way music is handled, such as sensation-seeking or extraversion. It has been argued that high-sensation seekers have a higher need for arousal and low-sensation seekers have a lower need for arousal (Litle & Zuckerman, 1986). This suggests that high and low sensation seekers might also differ in the way they deal with music and the radio, and especially demanding types of music or radio. For example, while loud music can provide an optimal level of arousal for a high-sensation seeker, it might overload a low-sensation seeker. So, future research should try to replicate the current findings in different samples and by also taking into account the personality and individual difference factors that might interact with the way music/radio is being handled.

Finally, we focused on several strategies and processes via which music and the radio influences performance (i.e., regulation of mental effort, blocking-out audio distracters, arousal). However, an even more common strategy to employ when overloaded by music or the radio might be simply turning off the auto-tape or lowering the volume. The participants in the current studies did not have control over the audio source, because our main aim was to investigate how continuous exposure to music or the radio influences performance in high and low-complexity traffic settings. Yet, future research might aim at examining how drivers regulate demands via a controlled exposure to music or the radio in environments varying in complexity.

Conclusion

In sum, how and to what extent music and radio-listening influences driving performance depends on the complexity of traffic, and therefore, on the demands induced by the driving task. In high-complexity traffic settings, drivers make use of compensatory strategies such as regulation of mental effort and attentional resources (Chapter 2 and 3). As a result of such strategies, the driving task is prioritized over the secondary tasks of music and radio-listening, and driving performance is secured.

In very low-complexity traffic settings, music seems to influence driving performance through a different process: by increasing arousal closer to optimal (Chapter 4). So, music or the radio provides drivers with some external stimulation that helps them to stay vigilant in very low complexity traffic settings, as a result of which the driving performance is maintained. Importantly, in neither of the studies, we found an evidence for impairment in driving performance as a result of music and radio-listening. Moreover, we found that some aspects of driving performance were even improved while listening to music (Chapter 2 and 4), meaning that both the strategies employed and the processes via which music and radio influences performance are working well in prioritizing driving safety.

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Nederlandse Samenvatting

Luister je graag naar muziek tijdens het autorijden of rijd je liever in stilte zonder enige externe prikkels? Onderzoek suggereert dat de meerderheid van de automobilisten de radio aanzet of naar muziek luistert, meestal uit gewoonte zonder er bij na te denken (Dibben & Williamson, 2007; North et al., 2004). Automobilisten zeggen dat het luisteren naar de radio of muziek geen invloed heeft op hun rijgedrag. Heeft het luisteren naar muziek of de radio inderdaad geen invloed op het rijgedrag, of leidt dit tot een verslechtering of zelfs verbetering van hun rijprestaties? In dit proefschrift bestuderen we deze onderzoeksvragen. Daarbij richten we ons vooral op de processen die verklaren of en hoe het luisteren naar de radio of muziek invloed heeft op rijprestaties. We veronderstellen dat de context waarin er naar de radio of muziek wordt geluisterd bepaalt of en hoe rijprestaties worden beïnvloed door luisteren naar muziek of de radio (Scherer & Zentner, 2001). Daarom onderzoeken wij de effecten van het luisteren naar muziek en de radio in zowel hoog als laag complexe verkeerssituaties. Eerder onderzoek was vooral gericht was op de invloed van de kenmerken van muziek op de taakbelasting (Brodsky, 2002; Pêcher et al., 2009; North & Hargreaves, 1999). Wij richtten ons op de invloed van kenmerken van de taak (bijvoorbeeld of er veel verschillende verkeersincidenten zijn waarop men moet anticiperen versus een monotone situatie) op taakbelasting. Meer specifiek beredeneerden wij dat kenmerken van de taak in belangrijke mate bepalen hoe belastend men het vindt om te rijden in de auto terwijl men naar muziek of de radio luistert. Daarom varieerden wij systematisch kenmerken van de rijtaak om de taakbelasting te manipuleren. Daarnaast hebben we onderzocht of er sprake is van een interactie tussen invloed van kenmerken van de muziek (bijvoorbeeld laag of hoog volume; Hoofdstuk 2 en 4) en kenmerken van de taak (verkeersomgevingen met lage of hoge complexiteit) op rijprestaties.

In deze samenvatting bespreken we de belangrijkste bevindingen van ons onderzoek, gevolgd door een overzicht van de praktische implicaties van deze bevindingen.

De invloed van audiostimuli op rijprestaties in complexe verkeerssituaties

In complexe verkeerssituaties moet men omgaan met veel verschillende risicovolle verkeerssituaties en continue rekening houden met het gedrag andere verkeersdeelnemers. Dit soort situaties worden gekenmerkt door hoge moeilijkheid van de taak en hoge mentale belasting (Fuller et. al., 2008). In dit soort verkeerssituaties zou de moeilijkheid en mentale belasting van de rijtaak nog verder kunnen toenemen als er sprake is van een secundaire taak, zoals het luisteren naar muziek of de radio. Om in dit soort situaties om te kunnen gaan met een hogere mentale belasting kunnen automobilisten de rijtaak prioriteit geven en minder aandacht geven aan de afleidende secundaire taak, zoals het luisteren naar de radio. Maar zijn automobilisten wel in staat om de rijstaak te prioriteren als ze naar de radio of muziek luisteren? Welke processen spelen een rol in deze taakprioritering terwijl er naar de radio of muziek wordt geluisterd in een complexe verkeersomgeving?

Hockey (1997) stelt dat mensen de hoofdtaak kunnen priorteren door regulatie van mentale inspanning. Mentale inspanning is een indicator voor de mentale belasting die men ervaart tijdens een taak (Zijlstra, 1993). Tijdens het rijden kan een toename van mentale inspanning door het luisteren naar muziek of radio ertoe leiden dat mensen prioriteit gaat geven aan de rijtaak, en zich meer gaan concentreren op deze primaire taak. Een andere strategie die men kan toepassen om beter te presteren op de primaire taak is het reguleren van aandacht (Kahneman, 1970). Als deze strategie wordt gebruikt door autorijders, zullen zij vooral aandacht schenken aan taken die het meest belangrijk worden gevonden, terwijl zij geen of minder aandacht schenken aan taken die minder belangrijk zijn. Daarom kan worden verwacht dat aan de primaire taak, in dit geval autorijden, een hogere prioriteit wordt gegeven en dat deze dus meer aandacht krijgt dan secundaire taken, zoals het luisteren naar muziek of de radio. Wij veronderstellen dat automobilisten gebruik maken van beide compensatiestrategieën die hierboven zijn besproken, dus zowel regulatie van mentale inspanningen als regulatie van aandacht als ze naar muziek of de radio luisteren tijdens het autorijden in complexe verkeerssituaties. Belangrijk hierbij is dat we verwachtten dat door het gebruik van deze compensatiestrategieën de rijprestaties in complexe en risicovolle verkeerssituaties worden gewaarborgd of zelfs kunnen verbeteren. We hebben deze hypotheses getoetst in Hoofdstuk 2 en Hoofdstuk 3 van dit proefschrift.

Hoofdstuk 2: Heeft muziek invloed op mentale inspanning en rijprestaties in complexe verkeerssituaties?

In Hoofdstuk 2 van dit proefschrift onderzoeken we hoe en in welke mate muziek invloed heeft op rijprestaties in complexe verkeerssituaties waarin men moet omgaan met veel verschillende risicovolle situaties (bijvoorbeeld een geparkeerde auto die plotseling een parkeerplaats verlaat). Op basis van Hockey's 'Compensatory Control Model' (1997) voorspelden we dat de mentale inspanning van bestuurders die naar muziek luisteren hoger zou zijn dan de mentale inspanning van bestuurders die niet naar muziek luisteren. We verwachtten dat deze toename in mentale inspanning van automobilisten die luisteren naar muziek of de radio een indicatie is van het gebruik van compensatiestrategieën die men gebruikt om prioriteit te geven aan de rijtaak. We verwachtten dat deze cognitieve compensatiestrategieën effectief zullen zijn om de rijprestaties op het gewenste niveau te houden, en dat bestuurders die naar muziek luisteren daarom even goed zullen rijden als bestuurders die niet naar muziek luisteren. Verder verwachtten we dat een mogelijke verbetering van de rijprestaties tijdens het luisteren naar muziek of de radio verklaard kan worden door een toename in mentale inspanning, en dus het gevolg zou moeten zijn van de prioritering van de rijtaak. Met andere woorden, als men beter gaat rijden als men naar muziek luistert, dan zou deze relatie gemedieerd moeten worden door een toename in mentale inspanning.

De resultaten bevestigden onze verwachtingen. Automobilisten die naar muziek of de radio luisterden rapporteerden een hogere mentale inspanning dan automobilisten die niet naar muziek luisterden. Deze toename in mentale inspanning tijdens het luisteren naar de radio of muziek was gedurende de hele rijtaak aanwezig, en was dus onafhankelijk van het type taak en type risicovolle gebeurtenis die men tegenkwam in de complexe verkeerssituatie. Zoals verwacht was de mentale inspanning hoger wanneer de situatie meer risicovol was en er dus een grote kans was om bij een ongeluk betrokken te raken (bijvoorbeeld een geparkeerde auto die plotseling de parkeerplaats verlaat), dan wanneer de situatie minder risicovol was (bijvoorbeeld als deelnemers een andere auto moesten volgen). De aanwezigheid van muziek leidde echter ook tot een hogere mentale inspanning in minder complexe situaties. Deze resultaten suggereren daarom dat het luisteren naar muziek of de radio in verkeerssituaties die complex en veeleisend zijn extra cognitieve belasting oproepen. Dit is af te lezen aan een toename in mentale inspanning, die het resultaat is van de inspanning die deelnemers zich getroosten om prioriteit te geven aan de hoofdtaak (de rijtaak), en zich niet af te laten leiden door secundaire taken (luisteren naar muziek of de radio). Maar leidde het gebruik van deze compensatiestrategie er ook toe dat de rijprestaties niet slechter werden?

Onze resultaten wijzen erop dat de toename in mentale inspanning inderdaad succesvol was om de rijprestaties op het gewenste niveau te houden, aangezien bestuurders die naar muziek of de radio luisterden even goed presteerden als bestuurders die niet naar muziek luisterden. We vonden zelfs dat automobilisten die naar de radio of muziek luisterden op sommige aspecten beter presteerden dan automobilisten die niet naar de radio luisterden. We vonden bijvoorbeeld dat bestuurders die naar muziek luisterden eerder remden in een van de meest risicovolle situaties – namelijk een geparkeerde auto die de parkeerplaats plotseling verliet – om een botsing te voorkomen dan degenen die niet naar de radio of muziek luisterden. Daarnaast reageerden bestuurders die naar muziek luisterden sneller op snelheidsveranderingen van een auto die ze moesten volgen dan deelnemers die niet naar muziek luisterden. Alleen in deze laatste situatie bleek (conform de verwachting) het positieve effect van muziek op rijprestatie te worden gemedieerd door een toename in mentale inspanning. De resultaten wijzen er daarom op dat het reguleren van mentale inspanning tijdens het luisteren naar muziek een effectieve strategie kan zijn om rijprestaties op een gewenst niveau te houden, maar dat er ook andere processen een rol kunnen spelen die verklaren waarom rijprestaties niet verslechteren of zelfs verbeteren als men naar muziek of de radio luistert. In Hoofdstuk 3 gaan we na of een andere strategie ook een rol speelt om te zorgen dat rijprestaties niet verslechteren in complexe verkeerssituaties terwijl men naar muziek luistert: het reguleren van aandacht.

Hoofdstuk 3: Besteden automobilisten in complexe verkeerssituaties minder aandacht aan de radio?

Kahneman (1970) stelde dat mensen de hoofdtaak kunnen prioriteren boven secundaire taken door het reguleren van aandacht. Wanneer mensen deze strategie toepassen, zal de prestatie op de primaire taak naar verwachting gelijk blijven ten koste van de prestatie op een secundaire taak. Op basis hiervan veronderstelden wij dat automobilisten die naar de radio luisteren in complexe situaties ook hun aandacht reguleren om goed te blijven presteren op de hoofdtaak: het autorijden. Specifiek verwachtten we dat automobilisten in dat geval hun aandacht vooral richten op de hoofdtaak (autorijden) en minder aandacht geven aan de secundaire taak (luisteren naar de radio of muziek), vooral in complexe verkeerssituaties. Wij noemen dit proces het 'blokkeren van radio-inhoud' en we hebben dit gemeten door na te gaan hoeveel men zich na afloop van een rit kan herinneren van een radioprogramma waar men naar heeft geluisterd tijdens de autorit.

We veronderstelden dat de neiging tot het blokkeren van radio-inhoud afhankelijk is van de eisen die de rijtaak stelt aan de bestuurder. Onze eerste hypothese was daarom dat men zich minder zou herinneren van het radioprogramma waar men naar heeft geluisterd als men naar de radio luisterde tijdens het autorijden dan wanneer men geen andere taak uitvoerde. Verder verwachtten we dat de hoeveelheid geblokkeerde radio-inhoud groter is als er wordt gereden in een complexe verkeerssituatie (waar men 13 risicovolle situaties tegenkwam) dan in een verkeerssituatie die niet complex is (waar men 2 risicovolle situaties tegenkwam), omdat de eerste situatie veeleisender en meer mentaal belastend is. Tot slot verwachtten wij dat deze strategie, het blokkeren van radio-inhoud, een effectieve manier is om rijprestaties op het gewenste niveau te houden. Daarom verwachtten we dat automobilisten die naar de radio luisterden niet slechter zouden presteren dan automobilisten die niet naar de radio luisterden (controleconditie), onafhankelijk van de complexiteit van de verkeerssituatie.

Uit de resultaten blijkt dat de rijprestaties inderdaad niet werden beïnvloed door het luisteren naar de radio. Automobilisten die naar de radio luisterden presteerden net zo goed als automobilisten die niet naar de radio luisterden, zowel in de complexe als minder complexe verkeerssituaties. Om na te gaan of automobilisten inderdaad hun aandacht reguleren als ze naar de radio luisteren tijdens het autorijden gingen we na hoeveel automobilisten zich herinneren van de inhoud van een radioprogramma in vergelijking tot luisteraars die geen extra taak deden. Zoals verwacht blokkeerden automobilisten meer radio-inhoud, onafhankelijk van het type inhoud (i.e., muziekfragmenten, reclame, fragmenten van radio-interviews) dan mensen die geen extra taak deden. Mensen die geen extra taak deden leken beter naar een radioprogramma te luisteren en herinnerden zich meer van wat ze hadden gehoord dan automobilisten. Dit suggereert dat de aandacht die nodig is voor het besturen van een auto ervoor zorgt dat men minder aandacht besteedt aan een secundaire taak zoals het luisteren naar de radio.

Vervolgens hebben we getest of de neiging tot het blokkeren van radio-inhoud groter zou zijn bij automobilisten die rijden in een complexe verkeerssituatie dan in een minder complexe verkeerssituatie. Uit de resultaten blijkt dat automobilisten die reden in een complexe verkeerssituatie zich minder herinnerden van de inhoud van interviews die ze hoorden op de radio dan automobilisten die in minder complexe verkeerssituaties reden. We vonden echter geen verschillen in de hoeveelheid geblokkeerde radio-inhoud in complexe en minder complexe situaties voor muziekfragmenten en reclames. Dit betekent dat onze hypothese dat men vooral in complexe verkeerssituaties minder aandacht besteedt aan het luisteren naar de radio gedeeltelijk wordt ondersteund.

Over het algemeen wijzen de bevindingen in hoofdstuk 3 erop dat mensen radio-inhoud meer blokkeren als ze een rijtaak uitvoeren dan wanneer ze geen extra taak uitvoeren, en dat automobilisten die rijden in complexe verkeerssituaties de inhoud van radio-interviews meer blokkeren dan automobilisten die in minder complexe situaties rijden. Dit ondersteunt onze hypothese dat automobilisten hun aandacht reguleren en zich meer gaan richten op de hoofdtaak als de eisen en moeilijkheid van de taak toeneemt. Deze compensatiestrategie lijkt effectief te zijn, want de automobilisten die naar de radio luisteren presteerden net zo goed als automobilisten die niet naar de radio luisterden (de controleconditie). Deze bevindingen wijzen er dus op dat aandachtregulatie door het blokkeren van radio-inhoud een effectieve manier kan zijn om de primaire taak, het autorijden, voorrang te geven boven de secundaire taak, het luisteren naar de radio.

In hoofdstuk 2 en 3 onderzochten we of automobilisten in complexe verkeerssituaties cognitieve compensatiestrategieën toepassen als ze naar de radio of muziek luisteren. Maar wat gebeurt er in verkeerssituaties die helemaal niet complex zijn en die extreem monotoon zijn? Zijn er andere processen betrokken bij het luisteren naar de radio of muziek tijdens het autorijden in verkeerssituaties die niet complex zijn? Hoofdstuk 4 heeft tot doel antwoord te geven op deze onderzoeksvragen en om te begrijpen hoe en in welke mate muziek de rijprestatie beïnvloedt in verkeerssituaties met een lage complexiteit.

Hoofdstuk 4: Beïnvloedt muziek 'arousal' en rijprestaties in verkeerssituaties met een lage complexiteit?

Autorijden kan plaatsvinden in situaties die helemaal niet complex zijn waarin autobestuurders langdurig monotone taken moeten uitvoeren. Verkeerssituaties met lage complexiteit worden meestal gekenmerkt door een hoge voorspelbaarheid en de afwezigheid van externe prikkels (Wertheim, 1991). In dit soort situaties zal het niveau van 'arousal' van automobilisten laag zijn omdat ze weinig prikkels ervaren. Dit kan leiden tot verveling of slaperigheid, en kan de kans om betrokken te raken bij een ongeluk vergroten (Nelson, 1997; Thiffault & Bergeron, 2003). Verkeerssituaties die helemaal niet complex en monotoon zijn kunnen daarom ook veeleisend zijn, aangezien autobestuurders zich moeten inspannen om wakker te blijven en oplettend te zijn. We verwachtten dat het luisteren naar muziek of de radio autobestuurders kan helpen om in situaties oplettend te blijven, doordat hun 'arousal' wordt verhoogd tot een meer optimaal niveau. We testten deze veronderstelling door automobilisten te vragen om langdurig een andere auto te volgen in een monotone rijomgeving met een lage complexiteit.

Op basis van de Yerkes-Dodson wet (1908), die voorspelt dat mensen optimaal presteren als individuen een gemiddeld niveau van 'arousal' ervaren (terwijl prestaties minder optimaal zijn als dit 'arousal' niveau te hoog of te laag is), verwachtten we dat autobestuurders beter zouden presteren wanneer ze een gematigd niveau van 'arousal' hebben in plaats een laag niveau van 'arousal'. 'Arousal' hangt af van de complexiteit van de taak. Individuen een sterkere behoefte aan 'arousal' hebben wanneer ze taken moeten uitvoeren met een lage complexiteit, zoals een saaie taak (McGrath, 1963). In deze studie hebben we een verkeerssituatie gecreëerd die niet complex en erg monotoon was. Zowel de taak (het langdurig volgen van een auto die gelijkmatig reed) als de verkeerssituatie waren vrij voorspelbaar, waardoor automobilisten waarschijnlijk een laag 'arousal' ervaarden en behoefte hadden aan meer 'arousal' tijdens de rit. Daarom veronderstelden we dat het luisteren naar muziek tijdens een saaie monotone autorit zou leiden tot een hoger (en meer optimaal) niveau van 'arousal', en dat dit de rijprestaties zou bevorderen. Om deze assumptie verder te testen gebruikten we twee volumeniveaus van muziek, een hoog en gematigd volume. We verwachtten dat beide volumeniveaus zouden leiden tot een hoger niveau van 'arousal' tijdens de rijtaak dan een rijsituatie zonder muziek, en dat een hoog volume tot meer 'arousal' zou leiden dan een gematigd volume.

Naast het bestuderen van de invloed van het rijden en luisteren naar muziek op 'arousal' in verkeerssituaties met een lage complexiteit gingen we ook na of muziek invloed heeft op mentale inspanningen bij het rijden in verkeerssituaties met een lage complexiteit. We verwachtten dat in verkeerssituaties met een lage complexiteit autobestuurders een hogere mentale inspanning ervaren in de afwezigheid van muziek, terwijl de mentale inspanning lager zou zijn als automobilisten wel naar muziek luisteren tijdens het rijden. We veronderstelden dus dat het rijden in een monotone verkeerssituatie cognitief veeleisender is wanneer er geen externe prikkels zijn (in dit geval muziek). Daarom verwachtten wij dat mentale inspanning hoger is als men een monotone taak verricht en niet naar muziek luistert. Net als in de studies naar de effecten van muziek op rijprestaties in complexe verkeerssituaties verwachtten we ten slotte dat het luisteren naar muziek in monotone verkeerssituaties de rijprestaties niet verslechtert, maar dat muziek de rijprestaties in verkeerssituaties die niet complex zijn zelfs positief kan beïnvloeden, vanwege de verwachte positieve invloed van muziek op het 'arousal' niveau van automobilisten.

Zoals verwacht, vonden wij dat het luisteren naar muziek geen significante invloed had op de rijprestaties. Op sommige aspecten van de auto-volgtaak presteerden mensen die met muziek reden zelfs beter dan mensen die niet naar muziek luisterden. Ongeacht het volumeniveau, leidde het luisteren naar muziek tot het sneller opvolgen van snelheidsveranderingen van een andere auto die voor de persoon rijdt, wat inhoudt dat autobestuurders waakzamer zijn in het opvolgen van wat de auto voor hen deed. Daarnaast waren autobestuurders beter in staat om in een rechte lijn te rijden (en hadden ze dus een beter 'lateral control') wanneer ze naar muziek luisterden. Muziek lijkt dus inderdaad prestaties met betrekking tot het volgen van auto's te kunnen verbeteren wanneer iemand rijdt in een omgeving met lage complexiteit. Maar was de verbetering in prestaties gerelateerd aan het hebben van een hoog niveau van 'arousal' tijdens het luisteren naar muziek, en leidt het luisteren naar luide muziek tot meer 'arousal' dan het luisteren naar minder luide muziek?

We hebben 'arousal' gemeten aan de hand van zowel hartslagmetingen (in dit geval de gemiddelde hartslagfrequentie) en via zelfgerapporteerde niveaus van 'arousal'. Zoals verwacht hadden autobestuurders een hogere 'arousal' tijdens het rijden met muziek, wat werd bevestigd door zowel een hogere gemiddelde hartslag als zelf-gerapporteerde 'arousal' niveaus. Opvallend was dat het 'arousal' niveau niet samenhing met het volume van de muziek, wat betekent dat luide en gematigde volumes van de muziek zorgde voor evenveel 'arousal' tijdens het rijden in een verkeerssituatie met een lage complexiteit. Eveneens anders dan verwacht bleek de afwezigheid van muziek in dergelijke situaties niet te resulteren in een hogere mentale inspanning. Eerdere studies suggereerden dat men tijdens monotone ritten verveeld raakt en slaperig wordt, wat er toe kan leiden dat men zich meer mentaal moet inspannen om waakzaam te blijven (Warm, Parasuraman, & Matthews, 2008; Warm, Dember, & Hancock, 1996). Kennelijk leidde een taak waarin een auto diende te worden gevolgd niet tot een dergelijke onwenselijke staat. Wellicht neemt de mentale inspanning in monotone rijomstandigheden pas toe als men langer moet rijden en dus gedurende een lange tijd een gebrek aan 'arousal' ervaart. In toekomstig onderzoek kan worden getest of het luisteren naar muziek tijdens zeer langdurige monotone autoritten samenhangt met vermindering van mentale belasting en hoe dit vervolgens invloed heeft op de taakprestaties.

Samenvattend lijkt de aanwezigheid van muziek oplettendheid te verbeteren zoals was te zien in betere prestaties met betrekking tot het volgen van auto's. Belangrijk hierbij is dat in tegenstelling tot verkeerssituaties met een hoge complexiteit, niet mentale inspanning maar 'arousal' het mechanisme lijkt te zijn achter het in stand houden of zelfs verbeteren van prestaties in verkeerssituaties met een erg lage complexiteit.

Implicaties

In voorgaand onderzoek naar de invloed van muziek op rijgedrag werd weinig aandacht besteed aan de rol van omgevingsinvloeden. Wij stelden dat de mate waarin en hoe het luisteren naar muziek, of de radio, rijprestatie beïnvloedt afhankelijk is van de situatie waarin mensen autorijden. Daarom hebben wij hebben in onze experimenten, in tegenstelling tot eerder onderzoek, de complexiteit van de verkeerssituatie gemanipuleerd om de effecten van het luisteren van muziek op rijprestatie in verschillende verkeerssituaties te kunnen vergelijken. Uit de empirische studies die in drie hoofdstukken werden gerapporteerd blijkt dat het luisteren naar de radio of muziek geen negatieve invloed heeft op de rijprestaties, en soms zelfs kan leiden tot een verbetering van de rijprestaties. Ook toonden we aan dat er verschillende processen een rol spelen bij de invloed van muziek op rijprestaties in niet en erg complexe situaties. Dit proefschrift levert een waardevol inzicht voor zowel de theorie als de praktijk, omdat er meer inzicht is verkregen in de wijze waarop muziek invloed heeft op de rijprestatie in complexe en minder complexe verkeerssituaties.

In Hoofdstuk 2 en 3 gingen we na welke invloed het luisteren naar de radio of muziek heeft in complexe verkeerssituaties, waarbij automobilisten meerdere gevaarlijke verkeerssituaties tegenkwamen. Dit heeft ons in staat gesteld om niet alleen na te gaan of het luisteren naar muziek invloed heeft op generieke indicatoren van de rijprestatie, zoals het aantal snelheidsovertredingen, maar ook op specifieke indicatoren van de rijprestatie in complexe en gevaarlijke verkeerssituaties, zoals reactietijd en tijd die het kost om de auto tot stilstand te brengen. Onze bevindingen bieden ondersteuning voor de theorie dat in een situatie die mentaal belastend zijn mensen een onderscheid wordt maken tussen primaire taken en secundaire taken en zich vooral richten op het goed volbrengen van de primaire taak (in dit geval, de rijtaak; Hockey, 1997; Kahneman, 1970). Sterker nog, bestuurders die naar muziek of de radio luisterden reden niet slechter dan bestuurders die niet naar muziek of de radio luisterden; dit bleek zowel uit de algemene als specifieke indicatoren van de rijprestatie. Zoals verwacht pasten bestuurders die naar muziek luisterden cognitieve compensatiestrategieën toe tijdens het rijden, met name in verkeerssituaties met een hoge complexiteit, wat ze in staat heeft gesteld om even goed te rijden als bestuurders die niet naar muziek luisterden. Uit Hoofdstuk 2 bleek bijvoorbeeld dat de mentale inspanning toenam bij bestuurders die naar muziek luisterden, in alle verkeerssituaties. De resultaten van Hoofdstuk 3 suggereren dat automobilisten hun aandacht reguleren en meer prioriteit geven aan de rijtaak dan aan het luisteren naar de radio. De neiging om minder aandacht aan de radio te besteden werd zelfs sterker wanneer bestuurders in een complexe omgeving m moesten rijden. Bestuurders konden namelijk bepaalde dingen die ze hadden gehoord op de radio (bijvoorbeeld delen van interviews uit de radio-uitzending) minder goed herinneren, vooral in complexe verkeerssituaties. De resultaten van Hoofdstukken 2 en 3 ondersteunen dus de gedachte dat automobilisten compensatiestrategieën gebruiken als ze luisteren naar muziek of de radio in complexe verkeerssituaties, en hun aandacht vooral richten op de rijtaak en deze te prioritiseren, om zo te voorkomen dat hun rijprestatie slechter worden.

De verkeersomgeving die in Hoofdstuk 2 werd gebruikt (en voor een gedeelte in Hoofdstuk 3), die in beide gevallen complexe verkeerssituaties weerspiegelden, zullen automobilisten vaak tegenkomen in de bebouwde kom, waar men de weg vaak deelt met veel andere weggebruikers. Aangezien we in deze situaties geen verslechtering in rijprestatie hebben waargenomen bij automobilisten die luisteren naar de radio of muziek, kunnen we concluderen dat automobilisten goed in staat zijn om te gaan met de mogelijke afleiding die kan ontstaan door het luisteren naar de radio of muziek in complexe verkeerssituaties. Onze bevindingen ondersteunen het idee dat automobilisten die meerdere taken tegelijkertijd uitvoeren prioriteit geven aan de rijtaak en dat automobilisten in het algemeen veiligheid beschouwen als het belangrijke doel wanneer ze op de weg zijn (cf. Dogan, Steg, & Delhomme 2012).

In Hoofdstuk 4 hebben we ons specifiek gericht op de vraag hoe, en in welke mate, luisteren naar de radio of muziek de rijprestatie beïnvloedt in extreem monotone verkeerssituaties met een lage complexiteit. We hebben gevonden dat muziek de rijprestatie in verkeersituaties met een lage complexiteit via een ander proces beïnvloedt dan in complexe verkeerssituaties, namelijk via 'arousal'. Luisteren naar muziek leidt tot een hogere mate van 'arousal', waardoor het 'arousal' niveau op een meer optimaal niveau komt, en de rijprestatie soms zelfs verbeterd. Onze bevindingen laten dus zien dat de aanwezigheid van muziek de rijprestatie zelfs kan verbeteren wanneer de rijtaak monotoon is en de verkeerssituatie weinig complex is.

De gesimuleerde wereld die we in Hoofdstuk 4 hebben gebruikt komt overeen met verkeerssituaties die zich kenmerken door een hoge voorspelbaarheid en weinig verandering, zoals het rijden op snelwegen met weinig verkeer. Eerder onderzoek suggereerde dat dergelijke omgevingen tot zogenaamde snelheidshypnose kunnen leiden (Wertheim, 1991), wat betekent dat automobilisten moeite hebben om veranderingen in de omgeving waar te nemen door een tekort aan 'arousal', en dat automobilisten dan moeite hebben om hun aandacht te blijven richten op de rijtaak. Onze bevindingen suggereren dat het luisteren naar muziek of de radio automobilisten helpt om waakzaam te blijven in verkeerssituaties met een lage complexiteit, door het induceren van een meer optimaal niveau van 'arousal'. Op basis van deze resultaten van dit onderzoek kunnen we aanbevelen dat het luisteren naar muziek of de radio, gestimuleerd kan worden als men moet rijden in situaties die niet complex zijn om de nadelige gevolgen van het rijden in monotone omgevingen te bestrijden.

Een belangrijke bijdrage van de huidige studies aan de literatuur over de invloed van het luisteren naar de radio of muziek op rijprestaties is dat we meer inzicht hebben gegeven in de rol die eigenschappen van de taak hierbij spelen naast eigenschappen van de muziek. Eerdere studies trachtten de taakeisen te variëren door het manipuleren van kenmerken van de muziek (bijvoorbeeld tempo, volume; North & Hargreaves, 1999; Brodsky, 2002). Wij hebben daarentegen ons gericht op het manipuleren van de complexiteit van de verkeerssituaties, en veronderstelden dat dit invloed heeft op de mentale inspanning of niveau van 'arousal' die nodig is om de taak goed uit te voeren. De huidige studies laten zien dat eigenschappen van de taak inderdaad belangrijk zijn voor welke processen een rol spelen om rijprestaties te reguleren als men luistert naar muziek of de radio tijdens het rijden.

Meer specifiek hebben we gevonden dat op het moment dat de taakeisen relatief hoog zijn door de complexiteit van het verkeer, de aanwezigheid van muziek of de radio leidt tot het toepassen van compensatiestrategieën en dat de prioriteit wordt gelegd bij de belangrijkste taak, het autorijden (Hoofdstuk 2 en 3). Echter, deze strategieën worden niet toegepast tijdens het rijden in een omgeving met een erg lage complexiteit. In dergelijke verkeerssituaties heeft het luisteren naar muziek of de radio eerder een positief effect op de rijprestatie, omdat het bijdraagt aan het vergroten van de waakzaamheid doordat muziek of de radio het 'arousal' niveau op een meer optimaal niveau brengt (Hoofdstuk 4). Zowel in Hoofdstuk 2 als Hoofdstuk 4 hebben we ook de effecten van luide muziek op rijgedrag onderzocht. Ondanks dat het luisteren naar luide muziek als veeleisender wordt ervaren (North & Hargreaves, 1999), hebben we in geen van de studies gevonden dat het luisteren naar luide muziek leidde tot een verslechtering van de rijprestatie. Dit betekent dat zelfs veeleisende muziek tot een zekere hoogte getolereerd lijkt te worden door bestuurders. In Hoofdstuk 2 leidde luide muziek tot een toename in mentale inspanning. Dit suggereert dat men tijdens het luisteren naar luide muziek zich nog meer inspant om prioriteit te geven aan de belangrijkste taak (veilig rijden) in complexe verkeerssituatie. Een dergelijke toename in mentale inspanning werd niet gevonden als men luisterde naar muziek of de radio in een verkeersomgeving met een erg lage complexiteit (Hoofdstuk 4). Dit betekent, zoals we hebben beredeneerd, dat veeleisende muziek vooral leidt tot een vergroting van de taakvereisten als de taakvereisten al relatief hoog zijn, zoals in complexe verkeerssituaties. Dus, het lijkt erop dat rijtaakvereisten bepalen of men compensatiestrategieën toepast als men geconfronteerd met externe stimuli zoals muziek.

In eerder onderzoek is het luisteren naar muziek of de radio tijdens het rijden vaak geassocieerd met een toename in overtredingen en een groter risico op verkeersovertredingen (Brodsky, 2002). Er is zelfs een poging gedaan om een afspeellijst te creëren bestaande uit liedjes die hypothetisch gezien gemakkelijk zijn om naar te luisteren en de taakvereisten tijdens het rijden niet teveel zouden verhogen, waardoor het luisteren naar deze muziek de verkeersveiligheid niet in gevaar zou brengen (Brodsky & Kizner, 2012). Onze resultaten suggereren dat het luisteren naar de radio of muziek de rijprestatie niet verslechtert en dat het dus niet nodig is om een speciale afspeellijst samen te stellen en te promoten die hypothetisch gezien geschikt is om naar te luisteren tijdens het rijden en de veiligheid van bestuurders niet in gevaar zou brengen.

Conclusies

Samengevat, uit dit proefschrift blijkt dat hoe en in welke mate het luisteren naar de radio of muziek tijdens het autorijden de rijprestaties beïnvloedt afhangt van de complexiteit van de verkeerssituatie, en daarom van de eisen die worden gesteld door de rijtaak. Automobilisten maken in verkeerssituaties met een hoge complexiteit gebruik van compensatiestrategieën, zoals het reguleren van mentale inspanning en aandacht (Hoofdstuk 2 en 3). Een gevolg van het gebruik van deze strategieën is dat de prioriteit bij de rijtaak wordt gelegd en dat men minder aandacht besteedt aan secundaire taken zoals het luisteren naar muziek en de radio, zodat rijprestaties niet verslechteren. In verkeerssituaties met een erg lage complexiteit lijkt er een ander proces bepalend te zijn voor de invloed van muziek en de radio op de rijprestatie: luisteren naar muziek of de radio verhoogt 'arousal' van de bestuurder naar een meer optimaal niveau (Hoofdstuk 4). Het luisteren naar muziek of de radio biedt automobilisten dus externe stimulatie die hen helpt om waakzaam te blijven in verkeerssituaties met een erg lage complexiteit met als resultaat dat de rijprestatie niet verslechterd en soms zelfs verbeterd. Een belangrijk bevinding is dat we in geen van de studies bewijs hebben gevonden voor een verslechtering van rijprestaties als gevolg van het luisteren naar muziek of radio. We vonden zelfs dat sommige aspecten van de rijprestatie verbeterden tijdens het luisteren naar muziek of de radio (Hoofdstuk 2 en 4). Dit betekent dat de men op een effectieve manier omgaat met externe stimuli (zoals luisteren naar muziek of de radio) zodat de rijprestaties niet verslechteren en de verkeersveiligheid niet in gevaar komt.

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