The Influence of Podcasts on Driving Performance in Complex Environments, with a Potential Moderating Effect of Neuroticism

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PSB3E-BTHO: Honours Bachelor Thesis

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July 28, 2025

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Abstract

This study investigated how the addition of the secondary task, listening to a podcast, impacts driving in complex simulated environments, as well as if neuroticism plays a moderating role within this relationship. A within-subjects, repeated-measures design was employed with a sample of 26 participants, all of whom were required to complete the same simulated drive twice, once whilst listening to a podcast, and once without. Speed, speed variability, lane swerving, and two measures from a gap acceptance task were used to assess driving performance. Additionally, questionnaires yielded subjective performance measures, along with neuroticism scores and information on secondary task performance. Ultimately, listening to a podcast was not found to impact driving performance, nor was neuroticism found to be a moderator. However, in the exploratory analysis, significantly higher effort was experienced by the participants during the podcast driving condition, which in combination with overall poor secondary task performance, indicates a form of compensatory and adaptive behavior to protect primary task performance. Although multitasking increases cognitive strain on the participants, it seems that driving performance can be sustained through increased effort exerted. Regardless, exerting more effort may not be a sustainable strategy over longer or more complex drives since cognitive reserves will be used up faster. So, future research should explore how different environments, situations, and types of people may impact this relationship, and if the actual moderator may be effort.

Keywords: Driving, Dual-Task Performance, Cognitive Workload, Complex Environments, Simulator, Neuroticism, Podcast Listening

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Introduction

Distracted driving causes thousands of deaths each year, resulting in more than 3,000 fatalities in the United States in 2023 (National Highway Traffic Safety Administration, 2023). With the advancement of technology, many variations of automatic assisted driving systems have been added to cars, lowering the effort needed to operate the vehicle, seemingly leaving drivers with attention to spare (Hungund et al., 2021). Consequently, drivers can use that attention for other tasks, like operating a phone or attending to in-car entertainment (de Waard, 1996). Although these tasks may seem easy and effort-free, when the primary driving task becomes unexpectedly complex, they can cause drivers to miss important road events and details, posing a safety risk (de Waard & van Nes, 2021).

One task that has become more common in recent years is listening to podcasts. In contrast to passive background music, podcasts consist of narratively rich and cognitively demanding verbal content that requires continuous processing, attention allocation, and working memory engagement. As their popularity rises, it becomes increasingly necessary to investigate how listening to podcasts may affect driving performance, particularly in demanding scenarios and in conjunction with individual personality traits that influence cognitive flexibility and susceptibility to distraction.

The Role of Driving Environment on Cognitive Load

Driving requires the coordination of many different cognitive processes, visual, auditory, and motor, to be effectively performed. (de Waard, 1996; Wickens, 2008). Rasmussen (1983) and Reason (1990), propose three different levels of performance. One operates at an automatic skill-based level, the other at a rule-based level, requiring moderate effort with the final level indicating high effort and explicit knowledge retrieval, requiring deliberate action and active contemplation. According to this framework the more experience drivers gain, the more they tend to rely on automatic processing, reducing the mental effort required during routine driving situations, (de Waard & Lewis-Evans, 2014). However, the elimination of cognitive effort is not guaranteed simply because a driver is able to, at one point of the drive, operate at an automatic level. This is because, in unfamiliar or unexpectedly complex situations, drivers must adapt to the increase in cognitive demands, reliant on higher-level processing. In these moments, mental resources are reallocated, which reduces the attention available for anything outside of the immediate demands of the driving task, like a secondary task.

An important part in determining mental workload is played by the driving environment. Even when drivers feel as though they are functioning well on autopilot, the road environment, which is subject to change, can significantly influence their level of required attention. For instance, long and monotonous roads with little traffic may lead to passive fatigue, a gradual decline in attention that often occurs without the driver's awareness (Neubauer et al., 2012). On the other hand, elements like pedestrians, traffic, and intersections, make up complex environments, which rely on consistent decision-making ability, placing great cognitive demands on the driver, increasing safety risk, especially if the driver is already tired or distracted (Nowosielski et al., 2018).

Mental workload in driving is generally defined as the balance between the demands of the driving task and the available cognitive resources of the driver (de Waard, 1996). Dynamic in nature, this interplay is susceptible to a variety of factors like emotional state, personality traits, driving context, and driving experience (de Waard & Lewis-Evans, 2014). More specifically, the task-difficulty homeostasis theory (Fuller, 2005) posits that this balance is preferably maintained at a level of mental effort in which they feel calm and in control. In low-demand environments, this may be accomplished by engaging in secondary tasks, such as listening to music or a podcast, to stay mentally engaged (Nowosielski et al., 2018). Whilst in high-demand situations, drivers usually reduce or avoid such activities in order to focus on the primary task (Fuller, 2005; de Waard et al., 2011). The distraction hypothesis posits that the addition of a secondary task, especially one that requires continuous cognitive engagement, when mental resources are already under strain due to a complex primary task, can significantly impair task performance (De Waard et al., 2011). Thus, to determine if the addition of a secondary task whilst driving impairs or enhances performance, one must examine the allocation and distribution of cognitive resources.

Secondary Tasks and Podcast Listening

How cognitive resources are distributed and compete with one another is described by the Multiple Resource Theory (Wickens, 2008). According to this theory, there are a variety of cognitive resources available to people which are organized into different factions. Cognitive resources are split into stages of processing (e.g. working memory), codes of processing (how information is represented in the brain), and the modality dimensions, which are the different sensory input channels. When tasks that fall into distinct groups are managed simultaneously, there is less task interference than when coordinating tasks of the same modality. For instance, if two visual tasks must be handled in parallel, e.g. driving whilst texting on a mobile phone, performance in both tasks will worsen due to the interference caused by the reliance on the same type of cognitive resource. Contrastingly, due to the different modalities of cognitive resources required, auditory content may potentially be an acceptable secondary task to combine with driving. However, the varying forms of auditory content need to be examined since even though the modality dimension may differ, the ways of processing may intersect with those required for driving, as in the case of listening to podcasts.

Firstly, podcasts are specifically selected by drivers because the content must be relevant enough to retain their attention. In contrast, radio music is more random and, pre-selected, often serving as background stimulation requiring less cognitive effort (Nageswara et al., 2024). On the other hand, podcasts are a form of narrative auditory content that require active working memory to attend to, with research showing that driving worsens more when combined with emotionally stimulating audio stories than with neutral content (Horrey et al., 2017). This is a stage of processing that uses cognitive resources like memory engagement and intellectual involvement, also necessary for situational awareness and active decision-making whilst driving (Murphy & Greene, 2017). Thus, although there is not a lot of interference surrounding the modalities of the task, with driving being primarily visual, and podcast listening auditory (Wickens, 2008), there is an overlap within the allocation of resources which could hinder performance when task regulation is no longer possible due to overloaded resources (de Waard & van Nes, 2021; Murphy & Greene, 2017).

A type of mental effort regulation used by drivers is to compensate by increasing focus (Ünal et al., 2012), which is only effective up to a point. When both the podcast and the driving task demand significant attention by being complex and emotionally engaging, drivers may exceed their cognitive threshold (de Waard et al., 2011). According to Lewis-Evans and Rothengatter (2009), most drivers aim to stay within a subjective “comfort zone” of effort, but once this is exceeded, performance tends to drop sharply. Alarmingly, drivers may not notice that this threshold has been crossed, particularly if they are immersed in the podcast content (Sanbonmatsu et al., 2013), with the potential to lead to fatal driving errors.

Neuroticism as a Moderator for the Impact of Dual-Task Demands

How well someone handles distractions can be personality-dependent. For example, a relevant trait could be neuroticism, a trait marked by emotional instability, anxiety, and constant worry (Eysenck & Eysenck, 1968). People high in neuroticism are often stuck in their own thoughts, which interferes with working memory and makes it harder to stay focused on what is happening in their surroundings (Eysenck & Calvo, 1992), increasing the difficulty of multitasking. Studies have shown that neurotic individuals tend to perform worse in dual-task situations because they struggle more with blocking out irrelevant thoughts (Poposki et al., 2009). This trait has been linked to higher levels of fatigue during long, monotonous trips (Neubauer et al., 2012), more frequent self-reported distractions (Taubman-Ben-Ari et al., 2004), and more difficulty staying engaged on the task (Tewfik et al., 2024), generally leading to poor task performance (Wood et al., 2022).

At the same time, neurotic individuals are also more likely to seek out distractions. Okati-Aliabad et al. (2024) found that people high in neuroticism often turn to music or their mobile phones whilst driving to manage boredom or regulate negative emotions. However, since they struggle with efficiently handling cognitive interference, the added strain from these secondary tasks increases difficulty (Poposki et al., 2009). For drivers high in neuroticism, podcasts are not just a passive background feature but can become an extra load that they are not equipped to handle.

Research Gap and Hypotheses

Although there is extensive research on driving distractions, the influence of listening to podcasts while performing another task, despite podcasts being a common and cognitively complex form of media, remains understudied. Most prior work focuses on secondary tasks of a visual (e.g. texting), or passive audio (e.g. music) nature. The interactive, story-driven nature of podcasts poses a different kind of cognitive challenge. By being a secondary task that could interfere with the working memory resources needed for driving, the podcast could cause a detriment to the primary task, regardless of them having distinct modalities (Wickens, 2008). Additionally, there is limited research on how personality traits like neuroticism might play a role in how different people manage dual-task performance.

Study Aims

This study addresses these gaps by examining how listening to narrative-driven audio content in the form of a podcast as a secondary task affects driving behavior in a complex simulation, and whether neuroticism had a mitigating influence. The purpose of this research is three-fold. Firstly, it will allow for more discovery on how different personality factors influence, not only driving but performance in general, when under a higher cognitive load. Furthermore, possible differences in types of auditory content may be highlighted, calling for more distinction in future research which also has the real-world applicability that just because it is the norm to use auditory stimulation whilst driving, does not mean that a safety risk cannot occur in response to specific forms of content and context. The following question grounds the research of the subsequent paper to explore this topic in greater detail: How does listening to podcasts affect driving performance in complex situations, and does neuroticism play a moderating role?

Taken together, this discussion resulted in the following hypotheses:

H_1: In complex driving conditions, listening to a podcast will be associated with worse driving behavior, exhibited through slower speed, more speed variability, lane swerving, and smaller gap acceptances

H_2: Neuroticism scores will moderate the relationship between podcast condition and driving performance; specifically, those with higher neuroticism scores will perform worse at driving given the addition of the secondary task

H_3: Driving will be prioritized over listening to the podcast to protect performance, reflected in poor secondary task performance

Method

Participants

The aim of this study was to attain a final sample size of at least 24 participants, for whom holding a driver's license was the only prerequisite for participation. No financial compensation was offered for participation, and all participants were required to sign a consent form in line with the guidelines of the Human Ethics Committee of the University of Groningen. On the basis of a checklist developed by the Ethics Committee of the Faculty of Behavioral and Social Sciences at the University of Groningen, the study was exempt from full ethics and privacy review (study code PSY-2425-S-0240).

Materials

Questionnaire

Qualtrics survey software (Qualtrics, Provo, UT) was used to administer the questionnaires that were filled out by participants on a laptop throughout the experiment. In addition to gathering demographic data including participants' age and gender, the first part of the questionnaire also asked about a variety of driving experience aspects, for instance rating their own driving skills, how long they have been a licensed driver, how often, on average, they drive each month, as well as how often and what kinds of podcasts they listen to whilst driving. Following this, participants were asked to complete questionnaires that measured the moderating personality variables. Susceptibility to peer pressure was measured using the Peer Pressure and Risky Driving Scale (Trógolo et al., 2022), and neuroticism scores were assessed using the 48-item revised version of the psychoticism scale (Eysenck et al., 1985), where 12 items measure the personality trait in question and result in a score between zero and one. This first part of the questionnaire was designed to give a broad overview of the participants along with pertinent information about their backgrounds and personalities for the study.

Although given out at different points during the experiment, the second and third surveys were identical, with the aim of assessing the participants' evaluation of their simulated driving experiences after each trial. The questionnaire was based on a number of variables chosen from earlier studies. To begin with, participants were given a continuous slider scale to rate their level of activation during the task, starting at 0, representing “Not aroused”, to 10, representing “Very aroused”, with 5 representing “Neutral”. Next, the driving task was evaluated on a scale of 0 to 10, with 0 denoting “no effort,” 5 denoting “some effort,” and 10 denoting “extreme effort.” Using a scale of 0 (“Exceptionally poor”) to 10 (“Exceptionally well”), with 5 denoting “Normal,” participants also evaluated their own driving performance for each trial.

Finally, there was one additional questionnaire that only pertained to the podcast condition, used to assess how well the participants paid attention to the podcast. This operationalization of the secondary task performance included six multiple-choice questions about the content of the podcast clip listened to during the drive, with three answer options given.

Driving Simulator & Virtual Driving Environment

A modified Jenting 50 driving simulator (developed by STSoftware), supporting a simulated driving environment (see Figure 1 for the driving circuit), and real-time data collection, was used for the experimental trials (Sporrel et al., 2024). For increased ecological validity, the simulator was equipped with engine sounds, a car seat, a steering wheel, indicators, pedals for braking and accelerating, as well as an automatic transmission to simplify use. Additionally, it was fitted with a CKAS motion platform that provides motion feedback to the driver in response to the simulated driving. With the use of five 60-inch monitors, the visual setup resulted in an approximately 240-degree field of view for the driver. Furthermore, the virtual environment was created with the use of custom software, whilst the scripted scenarios enabled simulated traffic to mimic a realistic driving experience.

The participants were instructed to follow the road signs to their final destination, called “Venekerk”, which took around six minutes, with speed limits ranging from 50 to 80 km/h, to reach. The scenario included a range of additional tasks like paying attention to road signs, waiting for other vehicles and cyclists to pass, driving through different environments, avoiding obstacles on the road, and navigating intersections, to increase the complexity of the drive.

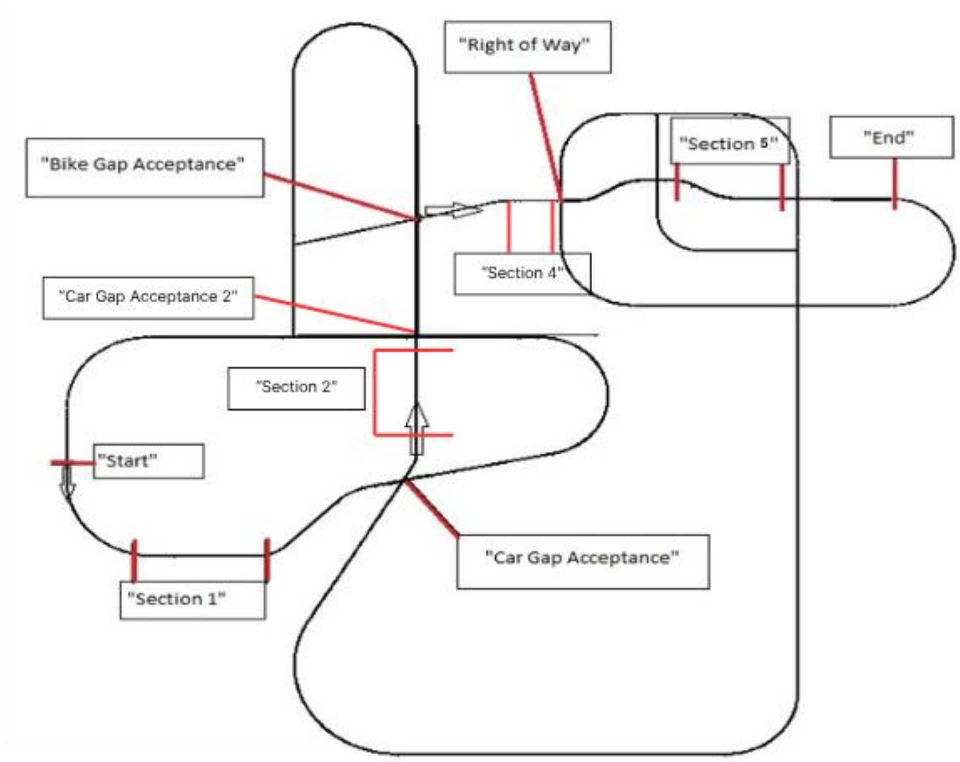
Gap acceptance tasks 1 and 2 in the driving environment, generated traffic at an intersection, where the gaps between cars increased with one-second increments (additional information can be found in Sporrel et al., 2024). Also relevant is how close the oncoming car came to the participant's car, providing information on the driver's safety margin. These measures reflected decision-making under time pressure, where smaller gaps suggested riskier choices and often indicated cognitive overload or poor situational judgment (Nowosielski et al., 2018). Reasoning for this could be that when people are less concentrated, they also become more distracted, meaning less attention can be paid to the distance of the oncoming car (Sörqvist & Marsh, 2015).

Further measures used to assess objective driving performance were speed, speed variability, and lane swerving. Speed, measured in km/h, signaled the average speed of drivers over a specific road section. This performance metric was included due to evidence indicating that distracted drivers tend to reduce speed as a compensatory mechanism for diminished attentional capacity (Oviedo-Trespalacios et al., 2017). On the other hand, speed variability, which indicated how consistently drivers maintained their pace over this section, was measured using the standard deviation of speed in km/h. Fluctuations in speed have been shown to be indicative of compromised vehicle control, particularly under multitasking conditions (Chen et al., 2019), with more variation suggesting loss of focus or emotional instability (Nowosielski, 2018). Finally, lane maintenance was evaluated using the standard deviation of lateral position (SDLP), which quantifies the variability in lateral position from the center of the driving lane in meters. By indicating how steadily the drivers kept their lane, higher SDLP is a reliable measure of reduced task performance which may indicate distraction or overload (van Dijken et al., 2020). SDLP serves as a robust indicator of lateral vehicle control and has been shown to increase in complex situations under dual-task performance, reflecting attentional interference and impaired steering precision (Brookhuis et al., 1991; Wang & Qin, 2025).

Speed, speed variability, and lane swerving were measured across two different sections of the route, section 2 and section 4 (see Figure 1), throughout both of which attention had to be paid to road signs. Section 2 was a relatively straight stretch of an A road located between two gap acceptance tasks, where the drivers encountered some oncoming traffic with a speed limit of 80km/h. On the other hand, section 4 consisted of a straight segment of country road following a bike gap acceptance task and an unconventional and narrow road with obstructive oncoming traffic, the speed limit being 60 km/h. Furthermore, this section preceded entering a town, significantly changing the scenery, meaning that there were a lot of different influences at work on the participant during section 4, making it more complex than section 2.

Figure 1

Outline of the Road Circuit



Podcast

For the experimental driving condition, the participants were given the same podcast to listen to throughout the entirety of the drive. This podcast was: Travel with Rick Steves, episode 742 Sharks; Beyond Havana; Pompeii starting at minute 6:53. The selection of this podcast was based on requiring audio content that was presumably unknown to most participants, as well as containing content that was interesting enough to pay attention to and subsequently answer questions about. Conversely, the podcast should not be stimulating to the point where participants would no longer pay any attention to the drive. Thus, a topic about travel, which contained no profanity or overly intense stimuli, but was still educational, was considered appropriate.

Procedure

Prior to starting the experimental trials, participants were asked to fill out a brief questionnaire, after which, they were introduced to the driving simulator and asked to complete a test drive in a practice environment. This allowed them to familiarize themselves with the simulator, since the controls and the feeling of driving in a computer-generated environment call for habituation. Participants were allowed to practice until they felt comfortable starting the experimental trials.

After the practice session, the experimental trial began, which was conducted in a different environment from the practice trial. Participants were given headphones using transparency mode, meaning that external noises would remain salient for them, either with or without a podcast playing, and were instructed to follow the road signs to “Venekerk”. Throughout each drive, participants encountered several challenging situations, like the gap acceptance tasks. At the end of the drive, they were asked to park the car and fill out a questionnaire. The entire experimental procedure was repeated for the second drive, in which participants were subjected to the podcast condition that they had not yet encountered, each lasting no more than eight minutes. For both conditions, the simulator system automatically recorded the dependent variables of objective driving performance, whilst the questionnaires obtained the subjective driving performance.

Analysis

Using IBM’s SPSS Statistics software package (version 27, IBM) a within-subjects, repeated-measures design, to offset the undue influence of limited resources, was executed in which one drive was conducted with, and the other without, additional auditory input in the form of the podcast. To minimize carry-over effects, counterbalancing the order in which the participants were exposed to both of the driving conditions was implemented. To investigate the effects of podcast conditions on objective driving performance, repeated-measures ANOVA analyses will be carried out. Since severe assumption violations were present for the section 4 measures of speed variability and lane swerving, a 2x2 repeated measures ANOVA could only be performed for speed. Analysis of the other objective driving performance measures relied on a singular point of data collection. This point was section 2 on the driving route for speed variability and lane swerving, and the subsequent gap acceptance task for measures of gap time and distance to the oncoming car. Furthermore, to investigate the influences of neuroticism as a moderator, separate linear regressions were run using the differences scores of the performance measures across conditions as the outcome- and the centered neuroticism scores as predictor variables.

Results

Due to driving errors during the simulator task like taking the wrong turn or colliding with another car, four out of the initial 31 participants, as well as one participant due to simulator sickness (Jerome & Witmer, 2002), had to be removed from the data set, resulting in a final sample size of 26 participants (18 females, 8 males). The participants had a variety of nationalities (German = 17, Dutch = 4, Other = 5), with an age range of 19-29 (M_{age}= 22.9, *SD* = 2.1), with 1-12 years of driving experience ($M_{experience}$= 4.5, *SD* = 2.3), and a mean occurrence of driving instances per month per participant was 5.6 days (*SD* = 6.8) with a minimum of 0 and a maximum of 25 days.

To better examine individual driving behavior, an analysis of the participant's demographic and subjective driving experience both within and outside of the experiment was conducted. Findings, shown in Table 1, show that most of the participants rated themselves as driving better than the average. Yet drivers still rated their exerted effort higher in the podcast condition compared to the no podcast condition. A small difference between conditions can also be observed for how participants evaluated the no podcast drive as opposed to the podcast drive.

Table 1

Descriptive Statistics for the General Questionnaire

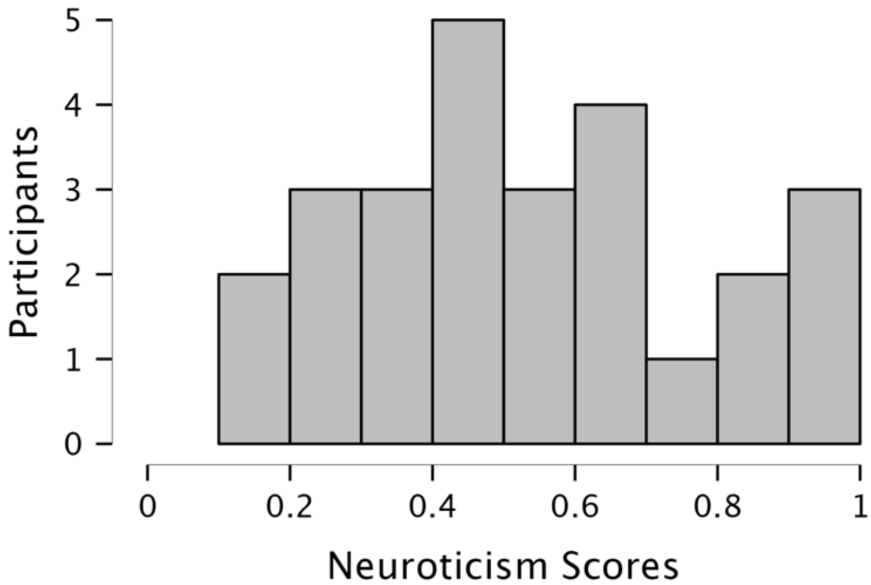
Variable	*M*	*SD*	*Minimum*	*Maximum*
Driving Self-Rating	5.81	1.67	2	8
No Podcast Exerted Effort	5.00	2.37	2	10
Podcast Exerted Effort	6.23	1.84	3	10
No Podcast Driving Self-Evaluation	6.39	1.75	3	9
Podcast Driving Self-Eval	6.00	1.36	3	9

Note. N = 26. Scores range from 1 (low) to 10 (high) for all; No Podcast is the no podcast listening condition; Podcast is the podcast listening condition.

After the 12 neuroticism items, from the Eysenck Personality Questionnaire-Revised Short Scale (EPQ-RS; Eysenck et al., 1985), yielded acceptable reliability (Cronbach's α = 0.751), the distribution of the scale score, with 0.00 indicating no neurotic tendencies and 1.00 indicating neuroticism across all of the items, resulted in a range of 0.17-1.00 ($M_{Neuroticism}$ = 0.54, $SD_{\text{Neuroticism}}$ = 2.45), as seen in Figure 2.

Figure 2

Histogram of Neuroticism Scores



Note. Participants ($N = 26$) with possible scores of 0.0 to 1.0 for the corresponding neuroticism scores.

In this study, five different outcome measures (speed, speed variability, lane swerving, gap distance, and distance to the oncoming car at the intersection, over two conditions (podcast vs no podcast) were analyzed as indicators of driving performance (for assumption checks, see Appendix). The first three variables were measured across two situations, however, for speed variability and lane swerving due to assumption violations, only measures from situation two will be analyzed, whilst the analysis for speed will retain all of the measurements, seen in Table 2.

Table 2

Descriptive Statistics of Objective Driving Performance

Measure	*M*	*SD*	*Minimum*	*Maximum*
NoP Speed (S2)	75.44	9.98	45.14	101.07
P Speed (S2)	74.31	9.05	46.32	91.42

Descriptive Statistics of Objective Driving Performance

Measure	*M*	*SD*	*Minimum*	*Maximum*
NoP Speed (S4)	57.68	7.12	41.79	68.80
P Speed (S4)	59.83	8.23	46.32	83.41
NoP Speed Variability	4.81	1.88	2.22	9.41
P Speed Variability	4.75	2.11	1.02	8.10
NoP Lane Swerving	0.13	0.05	0.06	0.31
P Lane Swerving	0.14	0.05	0.06	0.32
NoP Gap Time	3.46	1.17	2.00	6.00
P Gap Time	3.46	1.10	2.00	6.00
NoP Distance to Car	72.28	27.56	33.68	133.36
P Distance to Car	73.10	29.65	30.40	133.36

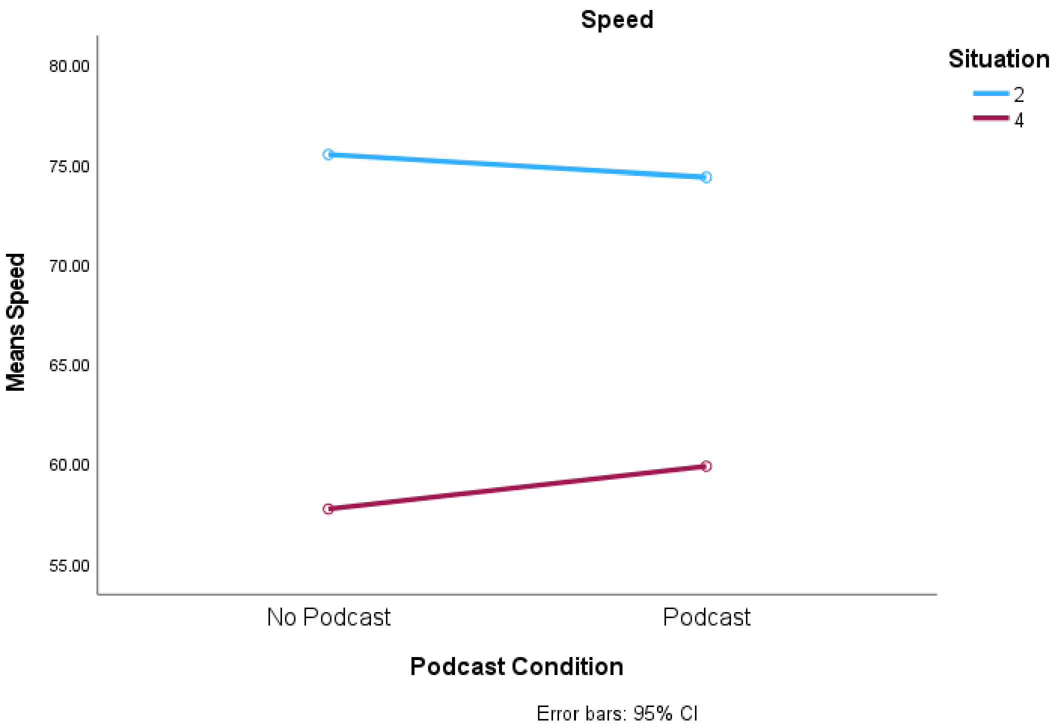
Note. Speed and Speed Variability are in kilometers per hour (km/h); Lane Swerving and Distance to Car are in meters (m); Gap Time is in seconds (s); S2 and S4 indicate the two different situations that measured this driving outcome; Speed Variability and Lane Swerving explicitly use S2; NoP is the no podcast listening condition; P is the Podcast listening condition.

Podcast Effects on Driving Performance

To investigate whether or not listening to the podcast elicits more risky driving behavior, a repeated measures ANOVA was performed for each of the five driving outcomes. A 2x2 repeated measures ANOVA indicated no significant effect of driving condition on speed, as seen in Figure 3, $F\ (1, 25) < 1$, $p = 0.613$, whilst Figure 4 shows no significant effects found for podcast condition on speed variability either, $F\ (1, 25) < 1$, $p = 0.894$. So, in this present sample, listening to a podcast did not significantly decrease the speed or speed variability during the driving tasks. Furthermore, no effect of podcast listening was found for lane swerving or distance to the oncoming car during the gap acceptance task, shown in Figures 5 and 6, respectively. Finally, concerning gap distances, with both conditions yielding the same mean gap time, repeated measures ANOVA results were likewise non-significant.

Figure 3

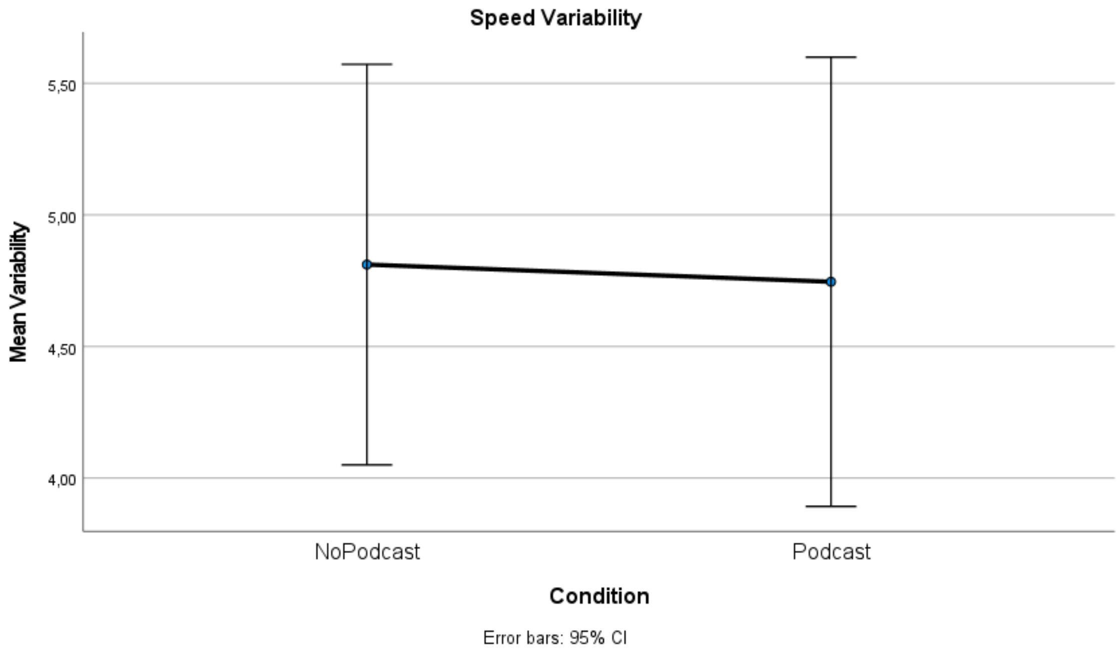
Comparison of Mean Speed Across Podcast Conditions and Situations



Note. Speed measured in km/h.

Figure 4

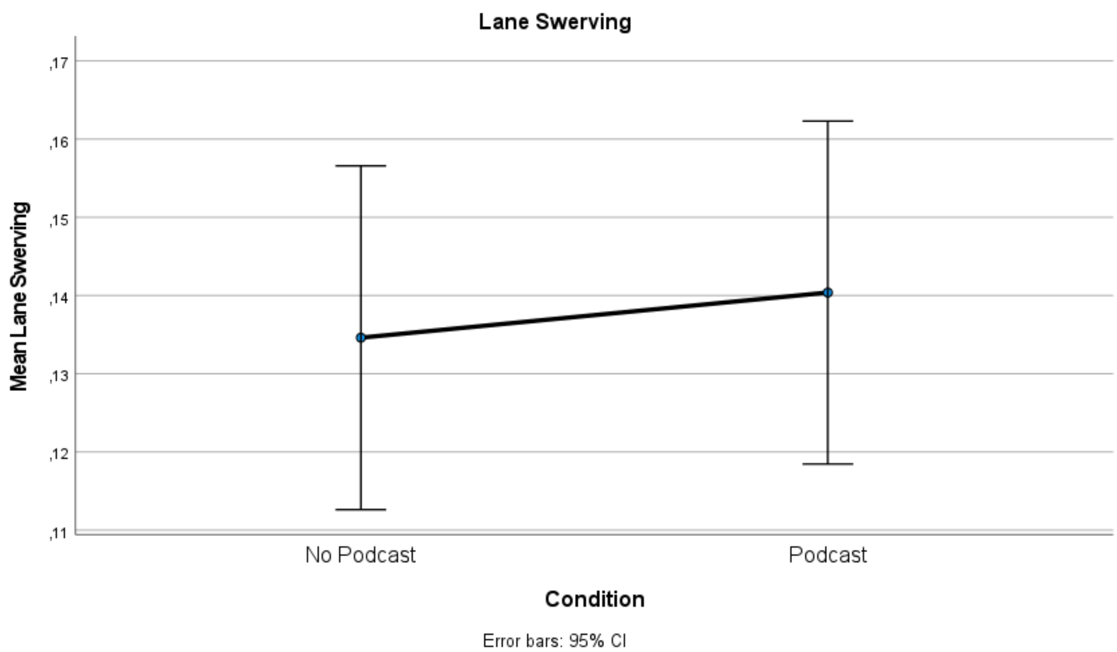
Comparison of Mean Speed Variability Across Podcast Conditions



Note. Speed variability measured in km/h. Error bars represent 95% confidence intervals (CI).

Figure 5

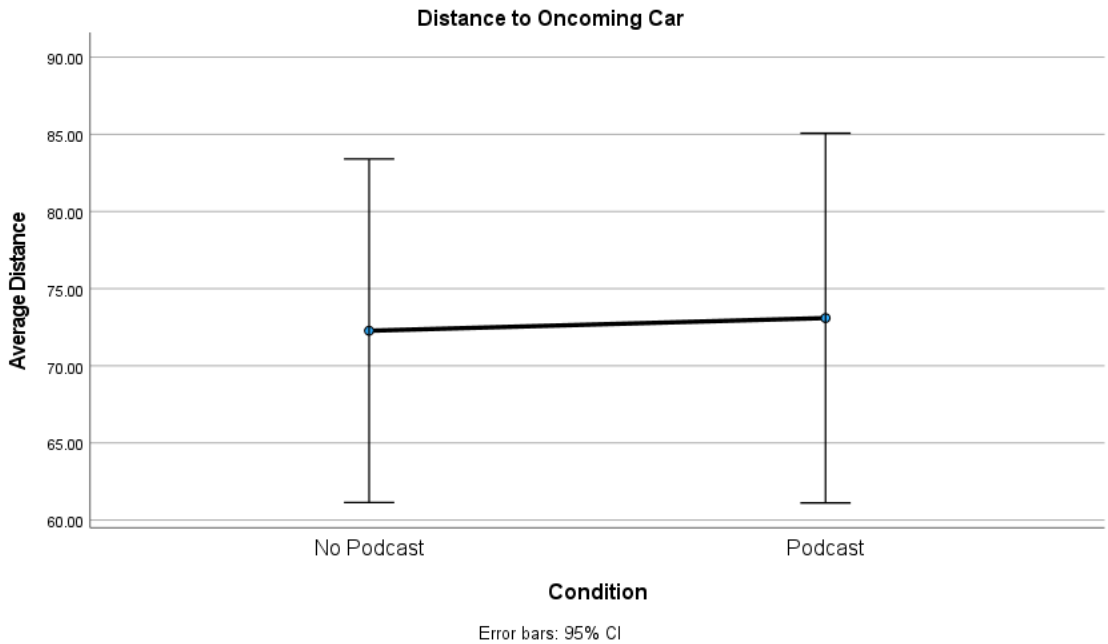
Comparison of Mean Lane Swerving Across Podcast Conditions



Note. Lane swerving measured in meters. Error bars represent 95% confidence intervals (CI).

Figure 6

Comparison of Mean Distance to the Oncoming Car Across Podcast Conditions



Note. Distance to the oncoming car measured from the center of the lane, in meters. Error bars represent 95% confidence intervals (CI).

Neuroticism as a Moderator

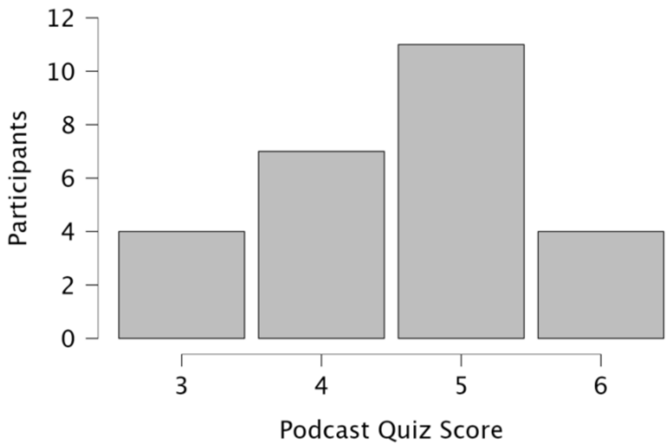
Regression models using centered neuroticism and the difference scores between conditions of the performance outcomes found that neuroticism did not significantly predict the strength of the condition's impact on driving speed, F (1, 24) = 1.75, p = 0.199, R^2 = 0.07. Furthermore, speed variability, also showed no significant moderation effect of neuroticism on driving performance at F (1, 24) = 1.06, p = 0.315, R^2 = 0.04. Similarly, results for lane swerving (F (1, 24) = 1.21, p = 0.282, R^2 = 0.05), gap distance (F (1, 24) = 1.41, p = 0.247, R^2 = 0.06), and distance to oncoming car (F (1, 24) = 2.20, p = 0.151, R^2 = 0.08), indicate no moderating effects.

Secondary Task Performance

The analysis of the secondary task performance, the score on the podcast content quiz, revealed a mean amount of 4.6 (*SD* = 1.0), out of six, correct answers, shown in Figure 7. The guessing rate, due to the multiple-choice nature of the quiz, means that for a pass participants had to score at least four points.

Figure 7

Distribution of the Podcast Quiz Scores



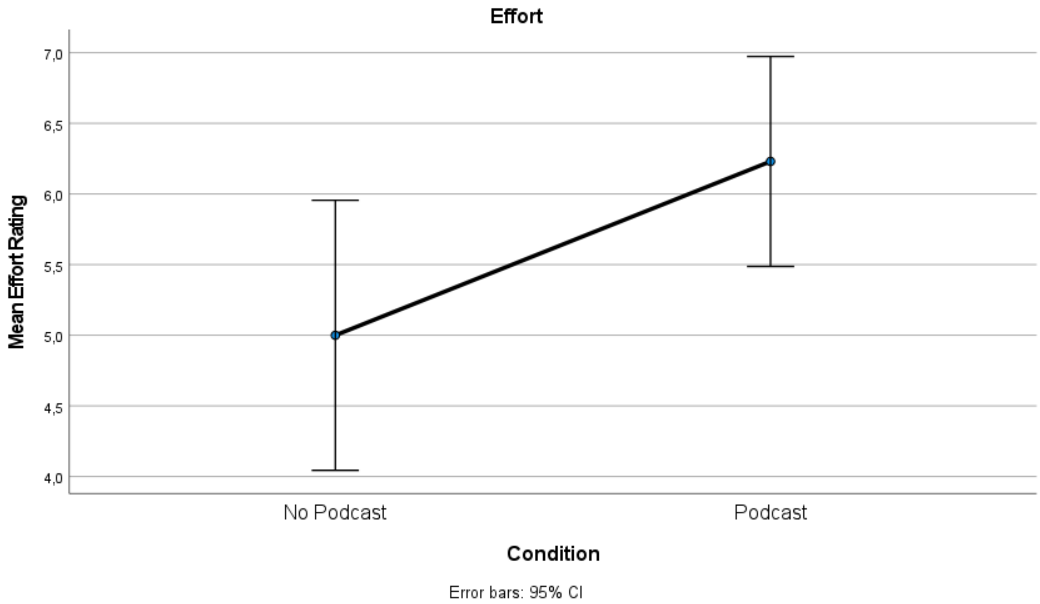
Note. Participants (*N* = 26); podcast quiz score (*min* = 1 and *max* = 6).

Exploratory Analysis

Since no significant effects of the podcast listening condition were found regarding the simulator's driving performance measures, a look at the questionnaire's subjective driving performance measures could offer some insight. Thus, a repeated-measured ANOVA of the effort ratings following each of the drives was carried out. This analysis revealed a significant effect of the secondary task, podcast listening, on the subjective effort exerted on the driving task (F (1, 25) = 11.11, p = .003). Figure 8 shows that the participants felt that they had to exert significantly more effort for the drive that included the podcast listening task.

Figure 8

Comparison of Mean Subjective Effort Exerted Across Conditions



Note. Effort rated from 0 to 10. Error bars represent 95% confidence intervals (CI).

Discussion

This study set out to examine whether listening to a podcast whilst driving would impair performance and whether neuroticism would moderate this effect. Interestingly, no significant differences were found between the podcast and no-podcast conditions for any of the main driving measures, speed, speed variability, lane swerving, gap acceptance, or distance to an oncoming car, meaning Hypothesis 1 was not supported. Neuroticism also did not significantly interact with the podcast condition for any of these outcomes, so Hypothesis 2 was rejected.

Nevertheless, the increased effort indicated by the subjective performance measures provides clear evidence that the podcast did have an influence on the driving experience. The unimpressive podcast quiz scores and significantly higher effort exerted during the podcast condition, despite maintenance of driving performance across conditions, support Hypothesis 3. To ensure that the primary task performance did not suffer, participants had to compensate by occasionally tuning out the auditory input and by exerting more effort to manage the increased workload. Thus, although no performance deficits were discovered, there appears to be a subtle but still meaningful compensatory strategy implemented by drivers in order to adjust to the higher task demands, which may have only been possible due to the drive and podcast not being complex enough. It is, however, still important to note that the secondary tasks' performance was sufficient, even if not necessarily satisfactory. This could indicate that participants only had certain moments where this compensation took place and that during different parts of the drive, their secondary task attentiveness was not impacted.

Theoretical Implications

These findings add to a growing body of research showing that drivers can adapt their behavior in response to increased mental workload (Brookhuis et al., 1991; Fuller, 2005). In this case, performance remained stable, but only because participants expended more effort and deprioritized the secondary task of listening. This supports the idea that distraction can lead to hidden cognitive strain even when driving behavior appears unaffected on the surface (de Waard, 1996).

The increase in self-reported effort and deficits in podcast recall is consistent with the notion that drivers desire to protect performance on the primary task by reallocating cognitive resources, in line with Multiple Resource Theory (Wickens, 2008). Since both driving and podcast listening rely on attention, drivers likely had to filter out some of the podcast content to stay focused on the road and maintain the elevated effort required. This matches earlier findings that secondary task performance typically suffers first during multitasking (Ismaeel et al., 2018; Oviedo-Trespalacios et al., 2017). However, an explanation for not finding clear effects could be that due to the different sensory modalities of the tasks, driving and podcast listening were easier to balance, which might not have been the case with a secondary task of a visual or spatial nature.

It is clear that the effects of distraction are context-dependent, but the potential role played by personality within this should not be overlooked. Since, previous research suggests that people high in neuroticism are more sensitive to stress and distractions, especially in situations that demand more cognitive effort (Tewfik et al., 2024; Wood et al., 2022), the relatively low-stress environment of the current study may not have triggered these differences. However, it is possible that personality factors would become noticeable in more demanding or high-pressure settings.

In short, the lack of obvious performance impairments does not mean there was no impact. As suggested by de Waard et al. (2011), drivers may still be under cognitive strain even when they appear to be performing normally. These results support the view that the secondary task did not cause visible breakdowns in performance, but it clearly made the task more mentally demanding, which is difficult to sustain over longer or more strenuous tasks.

Practical Implications

These findings give a mixed but generally reassuring view of podcast listening during driving. On the one hand, it did not lead to any noticeable drop in driving performance during the simulated drives. This suggests that for short, moderately complex routes, spoken-word audio may not pose a major safety risk. On the other hand, the added mental effort required to maintain driving performance, alongside poor recall of the podcast content, suggests that drivers may have been operating close to their cognitive limits. This raises concerns about how sustainable this kind of multitasking is over longer or more demanding drives.

Previous research has shown that a high mental workload, even when compensated for successfully, can lead to fatigue, slower reaction times, and reduced situational awareness over time (de Waard, 1996; Ünal et al., 2012). Drivers may not notice when they are approaching overload, and compensating for too long may eventually lead to errors.

Compensation needs to be context-sensitive, and should only be implemented for a short duration of time to be sustainable.

Suggesting an intuitive order of attention of focusing on the more urgent or safety-related tasks, most participants appeared to prioritize driving over listening to the podcast, matching earlier research showing that people tend to focus on the task they see as most important (Smith & Krajbich, 2018). Regardless, it is still important to remind drivers that when driving becomes more demanding, they should consider pausing or cutting back on other activities so as not to result in cognitive overload. Therefore, educating drivers about how attention and its limitations work may help them make safer choices.

Strengths and Limitations

A major strength of this study was its within-subjects design, enabling comparison between conditions whilst controlling for individual variability, increasing the reliability of the results. Additionally, a safe and controlled environment, that mimics real-world driving demands was provided via the use of the high-fidelity driving simulator. Another strength was the inclusion of both objective and subjective task performance measures by introducing measures of personality factors as well as driving experience. This provided a comprehensive analysis of cognitive demand, following long-standing recommendations for how best to approach assessing cognitive workload in driving research (de Waard, 1996).

On the other hand, the study also has its limitations, the most significant being the substantially small sample of mostly young, female, and European participants, which severely limits the generalizability of results. Furthermore, due to participants not having the option to select their own podcasts, motivation to listen may have also been limited. This was further exacerbated by the neutral topic of this study's podcast which may have failed at creating the necessary stimulation for podcast attentiveness, as opposed to more engaging and emotionally heightened auditory content, resulting in an underwhelming secondary task. The same can be applied to the driving scenarios themselves. If these had been more complex, for example driving during a snowstorm, the effects may have been more copious. Furthermore, the short drives did not allow for observations of long-term fatigue or cognitive overload to observe how they attempt to cope with needing to exert sustained effort. Even though data from various situations was available, no clear comparison was made to more closely examine the contextual differences and how these have particular impacts on behavior.

Future Direction

Given the exploratory results of this study, future research should also investigate if effort acts as a moderator in the relationship between performance and the addition of secondary tasks. Future studies should explore more demanding driving tasks, in terms of duration and scenario, along with varied types of audio input to test the limits of compensatory behavior. Including longer drives, more complex road scenarios, or physiological workload measures like heart rate or eye tracking could help address this. Allowing the participants to select their own podcast may also have an impact on the amount of attention allocated to the secondary task, since this tactic would ensure that the participants have intrinsic motivation to listen to the content of the podcast. Finally, this study focused only on neuroticism. Other traits, such as conscientiousness or sensation-seeking, may also play a role in how people respond to multitasking while driving (Taubman-Ben-Ari et al., 2004) and should be included in future work.

Conclusion

In conclusion, although there was no clear detriment to driving performance in relation to the podcast condition, the primary task did feel like it required more effort to execute when a secondary task was added. This suggests that in order to keep the driving performance at the individual’s preferred, and regular level, more effort had to be exerted. Performance was also protected by not prioritizing the secondary task, and subsequently not scoring well on the podcast content quiz. It seems that during dual-tasks individuals will prioritize the seemingly more important one to maintain and implement compensatory strategies accordingly. Finally, it can be concluded that listening to podcasts as a secondary task whilst driving is not inherently unsafe but depends largely upon the context since they will likely add to the driver's cognitive load. It should also be kept in mind that given more complex situations, the impact of personality factors on this relationship should not be excluded. It is likely that the average driver is able to effectively handle dual tasks effectively and maintain a solid driving performance under optimal conditions. Regardless, it is important to note that driving conditions can change momentarily and if drivers push their cognitive workload limits, they may not be in a position to adapt accordingly which could result in serious consequences. Taken together, this underlines the importance of understanding driving behavior and cognitive systems operating within this to support effective and, above all, safe driving.

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Appendix

Assumption Checks

Table 3 shows violations of the normality assumption by having Shapiro-Wilk p-values of lower than 0.05 for lane swerving and gap times in both conditions, as well as for speed in the no podcast listening condition. All other outcomes do not appear to deviate significantly from a normal distribution. The distributions for the violations, caused by outliers, can be seen in the figures below.

Due to the podcast conditions, the sphericity assumption is not of concern for the analysis. Normality was not significantly violated for either of the podcast conditions of speed in situation 4. Thus, the repeated measures ANOVA is suitable for the speed driving outcome variable. However, both lane swerving and speed variability show severe normality violations given their p-values for the Shapiro-Wilk test (Table 3), thus situation 4 was excluded for both of these measures.

Table 3

Normality Violations

Measures	*Shapiro-Wilk*	*P-value of Shapiro-Wilk*
NoP Speed (S2)	0.91	0.03
NoP Speed Variability (S4)	0.73	< .001*
P Speed Variability (S4)	0.78	< .001*
NoP Lane Swerving (S2)	0.88	0.005
P Lane Swerving (S2)	0.89	0.008
NoP Lane Swerving (S4)	0.79	< .001*
P Lane Swerving (S4)	0.80	< .001*

Normality Violations

Measures	*Shapiro-Wilk*	*P-value of Shapiro-Wilk*
NoP Gap Time	0.89	0.01
P Gap Time	0.90	0.02

Note. * = severe normality violations, the measures of which were excluded from analysis.

Figure 9

No Podcast Speed (S2)

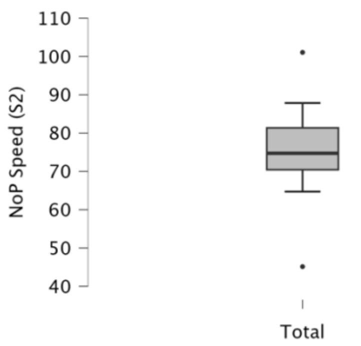


Figure 10

No Podcast Speed Variability (S4)

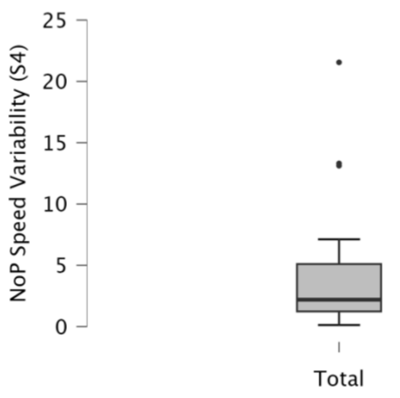


Figure 11

Podcast Speed Variability (S4)

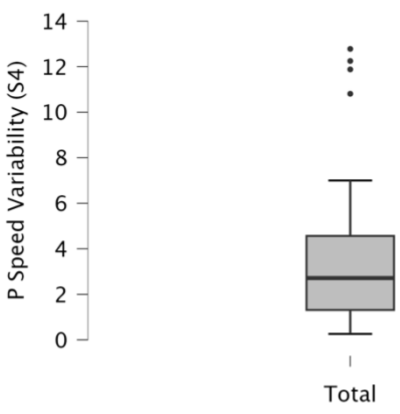
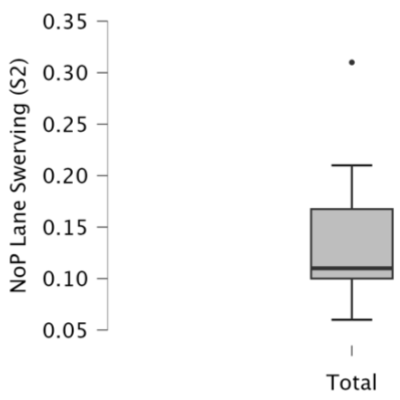


Figure 12

No Podcast Lane Swerving (S2)

Figure 13

Podcast Lane Swerving (S2)



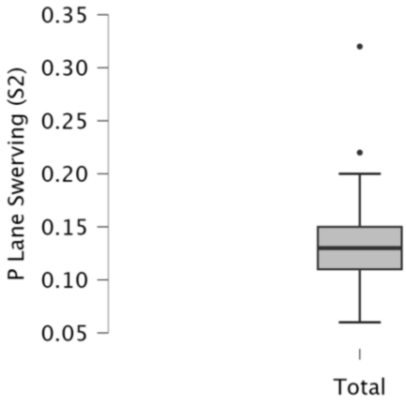


Figure 14

No Podcast Lane Swerving (S4)

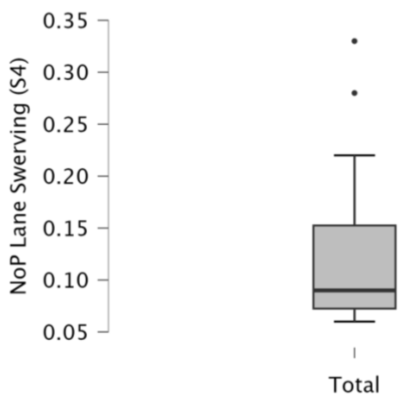


Figure 15

Podcast Lane Swerving (S4)

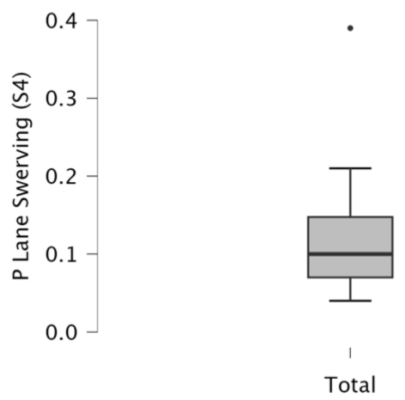


Figure 16

No Podcast Gap Time

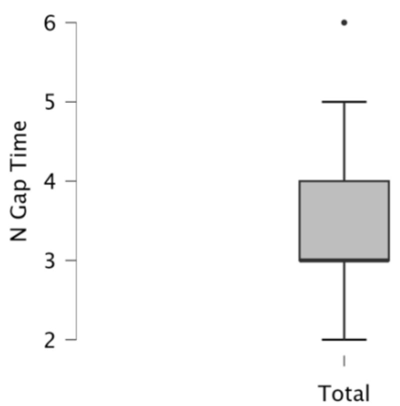
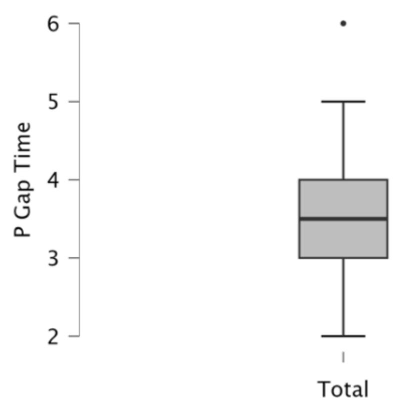


Figure 17

Podcast Gap Time



All of the outliers were caused by different participants, with gap occurrence being the only outcome with the same participant being the outlier for both conditions, reducing the risk of bias from idiosyncratic behavior. This suggests that it is valid to keep them in since it was not a mistake in the data, nor was it one participant driving suspiciously across all of the measures. Instead, these outliers indicate deviations that would occur in the real world as valid individual differences. Due to the robustness of repeated measures ANOVA, the violations are likely not prevalent or severe enough to disrupt the analysis. The sphericity assumption is also of no concern since the variances of the differences between all of the combinations of related conditions should be equal due to having two conditions per participant.