Beats vs. Talks: Alleviating Virtual Reality Sickness with Music and Podcasts

Lisa Neufeld
Technische Hochschule Ingolstadt
Ingolstadt, Bavaria, Germany
lin8347@thi.de

Elena Heim
Technische Hochschule Ingolstadt
Ingolstadt, Bavaria, Germany
elh5197@thi.de

Madita Joy Klinger
Technische Hochschule Ingolstadt
Ingolstadt, Bavaria, Germany
mak5618@thi.de

Chantal Himmels
BMW Group
Munich, Bavaria, Germany
chantal.himmels@bmw.de

Henrike Böck
Human-Computer Interaction Group
Technische Hochschule Ingolstadt
Ingolstadt, Bavaria, Germany
boeck.henrike@gmail.com

Andreas Riener
Human-Computer Interaction Group
Technische Hochschule Ingolstadt
Ingolstadt, Bavaria, Germany
andreas.riener@thi.de

Abstract

As virtual reality (VR) technology advances, its potential for widespread application increases. However, VR sickness (VRS) remains a major obstacle to broader adoption. This study investigates the effect of auditory stimuli on VRS during VR experiences. It contrasts the effects of music and podcasts, with a no-sound environment serving as reference. Twenty-three participants experienced three different auditory conditions during a VR roller coaster ride in a randomized, balanced order. VRS was quantified using the Simulator Sickness Questionnaire (SSQ) and physiological data. The SSQ results indicate that music significantly reduced oculomotor disturbances and disorientation, while podcasts had no positive effects. The physiological data demonstrated no significant effects. The majority of participants preferred the music scenario, describing it as relaxing and pleasant. This highlights the potential of music, especially when self-selected and perceived as pleasant, to improve VR experience by significantly reducing VRS. This effect appears to be independent of physiological data.

CCS Concepts

• **Human-centered computing → Empirical studies in HCI**.

Keywords

virtual reality sickness, simulator, music, podcast, simulator sickness

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1 Introduction

In recent years, virtual reality (VR) technology has advanced rapidly, drawing the public attention [13]. However, virtual reality sickness (VRS) is still a barrier to using VR in a variety of sectors, such as education, entertainment, and training, which has not yet been resolved [19]. VRS is generally considered a form of visually-induced motion sickness [34] and encompasses a wide range of general and specific health issues that users may encounter during a VR session, which could lead to adverse health effects. Various forms of sickness can emerge, such as motion sickness, cybersickness, and simulator sickness [2]. However, note that none of these terms is clearly defined and may refer to closely related concepts. VRS is polygenic and polysymptomatic, which means that not everyone is affected, and that the symptoms and severity can differ between affected users [34]. Unlike motion sickness, VRS does not require actual movement, as it often occurs due to a visual-vestibular conflict [1]. In immersive VR systems, users typically remain physically stationary, and their vestibular system signals a stable, upright position. However, the visual stimuli may suggest self-motion, resulting in a mismatch between the visual and vestibular information [14].

VRS is commonly attributed to two major contributing factor groups: human factors and technological factors. Human factors comprise gender, age, adaptation, exposure duration, motion sickness history, illness, medication, sleep, and fatigue attributes. In contrast, technological factors include Field of View (FOV), positioning, delays, flicker, calibration, ergonomics, controls, and tracking while using an HMD [2]. VRS usually manifests itself through nausea, disorientation, and/or oculomotor symptoms [15]. This can lead to discontinuations in user studies, which should be counteracted by taking breaks and drinking water for the benefit of the participant. It has also been speculated that, if users have an unpleasant initial VR experience, they will be reluctant to try it again [6]. Although several solutions have been proposed that aim to reduce the onset of VRS, a reliable approach for alleviating its symptoms within VR experiences has not yet been established [30].

1.1 Related Work

Previous studies have investigated possible factors influencing VRS. One of these factors is music, as shown in a study that assessed the mitigating effect of music on cybersickness: Kourtesis et al. [17] found that calming as well as pleasant/happy music significantly alleviated VR-related nausea. Another study from Keshavarz and Hecht [16] showed that music can efficiently reduce the severity of visually-induced motion sickness. However, the exact causal

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relationship of these positive effects of music on sickness is still unclear, while recent studies suggest that positive effects depend on the type of musical stimulus [16].

A study by Akiyoshi et al. [3] aimed to maximize passenger comfort in automated vehicles. A live XR music system was used to entertain passengers and reduce anxiety, and a motion platform was installed in the autonomous vehicle to generate moshing. In this context, moshing refers to a simulated, energetic crowd interaction that occurs in sync with vehicle turns, using collisions, motion effects, and audiovisual feedback to evoke the sensation of shared excitement. Participants experienced five conditions, including the real environment condition and environments with and without moshing. They found that the participants were unaware that they were driving in a virtual live music venue and perceived it like an amusement park attraction. The study also found that the video without the moshing function significantly enhanced enjoyment and reduced anxiety, compared to the real amusement park. This result is supported by the stress reduction due to the cognitive changes [3].

Another study investigated the effects of music on the VR player experience and, as a central factor, on the perception of time. Rogers et al. [31] found that the time in the VR game passed significantly faster in the perception of the participants when music was playing. Furthermore, listening to music is more than just a habit or a pastime for people [17]. One of the most common activities performed while listening to music is relaxation [23].

Similar to music, podcasts are often perceived as relaxing or entertaining [7]. Meanwhile, the influence of podcasts on VRS has not been thoroughly investigated. However, the relationship between cognitive demands and cybersickness in VR is discussed in the work by Pöhlmann et al. [29]. In this study, a significant effect of cognitive demand (task or no task) on motion sickness was observed. Participants experienced less motion sickness when they were performing a cognitive task compared to when they were not [29]. The positive effects of music on VRS may hence be attributable to cognitive demand. If so, podcasts should likewise reduce VRS. However, also the likewise relaxing effects of podcasts may induce a reduction in simulator sickness.

1.2 Contribution and Hypotheses

This paper aims to replicate the positive effects of music on VRS [16, 17]. Unlike previous studies, this allows participants to select their own music and explores whether other acoustic stimuli, particularly podcasts, can also alleviate VRS. Both conditions are compared to a no-sound condition serving as a reference value. Rather than using predefined music, we focus on music chosen by the participants themselves to take into account their natural preferences and maximize their emotional connection to the listening experience. Research indicates that the reduction of VRS is strongly dependent on the listener's subjective liking and familiarity with the music [27, 28].

To this end, three different auditory conditions (no sounds, music, podcasts) were empirically compared in a VR roller coaster simulation in the present study.

H1: Listening to music reduces the severity of VRS compared to a no-sound condition.

H2: Listening to podcasts reduces the severity of VRS compared to a no-sound condition.

H3: There is no difference in VRS between the music and the podcast conditions.

2 Methodology

2.1 Sample

The study was conducted with 23 participants, comprising 13 males and 10 females. The majority of the participants (n = 18) were aged between 18 and 25, with three participants aged between 26 and 32, and two participants aged between 33 and 40. All participants completed all three rides.

2.2 Design

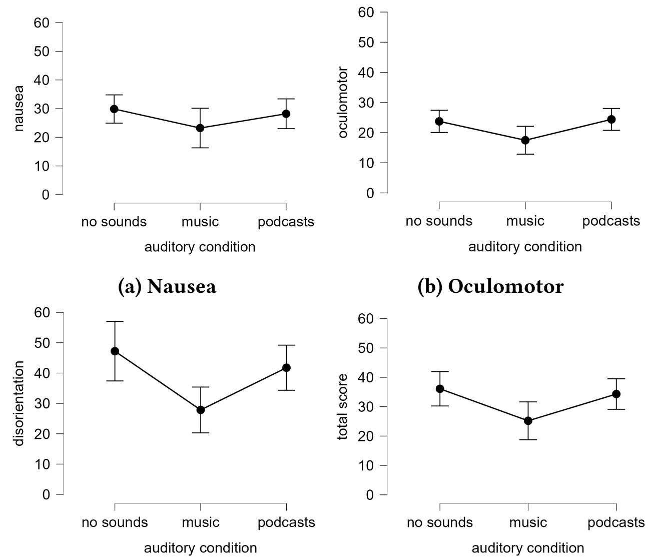
The study employed a within-subjects design to investigate the effects of different auditory environments (no sounds, music, and podcasts) on VRS in a roller coaster simulation (Figure A.1 in Appendix A). This design was chosen to ensure that each participant experienced all three auditory environments, thereby reducing the impact of individual differences in personal preference and susceptibility to VRS. To minimize sequence and carryover effects, and to provide systematic variation between participants, the conditions were presented in a randomized and counterbalanced order. This ensured that no single sequence predominated. The no-sound condition served as the reference condition. Subjective feelings of unpleasantness were inquired using the Simulator Sickness Questionnaire (SSQ) [15], complemented by post-experiment interviews. Electrodermal activity (EDA) and heart rate (HR) were recorded as objective measures of simulator sickness. Participants passively experienced the simulation without control over movement or direction of the virtual roller coaster. This lack of control is known to exacerbate motion sickness due to the mismatch between expected and perceived motion [32]. The design aimed to isolate the effects of auditory stimuli on VRS without interference of user control or interaction.

2.3 Material

Visual stimuli were delivered through a Varjo XR-3 headset. The VR simulation was based on the free Steam game "Epic Roller Coasters", which presented an ocean landscape with a standardized ride duration of 2 minutes and 30 seconds. The simulation included various track elements, such as sharp turns, sudden drops, loops, and rapid accelerations. Auditory stimuli were provided via Bluetooth noise canceling headphones (JBL LIVE660NC). Participants selected any preferred song and podcast episode from the Spotify application. For those without a preference, various categories were provided that encompass genres such as Hip-Hop, Pop, Rock, Rap, Techno, and Hardstyle for music, and thematic categories such as Comedy, Crime, News, Books, Science, and History for podcasts. Participants were seated on a stationary and ergonomic driver's seat. Physiological data were continuously recorded during each scenario using the Empatica E4 wristband, which captured EDA and HR at one second intervals. Ride timestamps enabled synchronization of physiological and experimental data. The SSQ [15] was administered before and after each condition to assess nausea, oculomotor disturbances, and disorientation. Participants rated sixteen symptoms on a four point Likert scale. The subscale and total scores were calculated following Kennedy et al. [15]. In addition to quantitative measures, qualitative interviews were conducted after the rides to retrieve more subjective information on presumed reasons for VRS.

2.4 Procedure

The participants were welcomed, briefed, and completed a pre-experiment SSQ to establish baseline VRS symptom levels. They were then equipped with the VR headset, headphones, and the Empatica E4 wristband. Each participant experienced the three auditory conditions in a counterbalanced order. Before the music and podcast condition, participants either selected their preferred audio content or received a prepared selection. For the podcast condition, a 30 second preview was played to familiarize participants with the podcast before the ride began. During each 2 minute and 30 second ride, participants passively observed the ride. After each condition, a post-condition SSQ was completed. To minimize the risk of VRS accumulation, a mandatory five-minute break was taken between experimental conditions. Participants were offered water and if they reported persistent VRS symptoms, the break was extended by an additional five minutes until they felt comfortable continuing. The session concluded with a post-experiment interview and debriefing to gather qualitative insights.



(a) Nausea **(b) Oculomotor**

(c) Disorientation **(d) Total score**

Figure 1: Effect of different auditory conditions on the mean values of the SSQ subscales. Error bars indicate 95% confidence intervals.

3 Results

The results of the study can be categorized into subjective ratings, including the SSQ results and qualitative data from subsequent interviews, and physiological measurements.

3.1 Subjective

3.1.1 SSQ results. We compared the total SSQ score and its three subscales as described by Kennedy et al. [15] across the three different auditory conditions using a repeated-measures ANOVA. The level of significance was set at α = 5 % for all statistical tests. Individual ANOVAs were carried out for the subscales disorientation, nausea, and oculomotor, as well as the SSQ total score. There was no significant effect of the auditory condition on the **nausea subscale**, $F(2, 44) = 1.56$, $p = .223$, $\eta_p^2 = 0.07$ (Figure 1a). For the **oculomotor subscale**, there was a significant effect of the auditory condition, $F(2, 44) = 3.91$, $p = .027$, $\eta_p^2 = 0.15$ (Figure 1b). The Bonferroni-corrected post-hoc tests indicate a significant difference between the music and podcast conditions. The **disorientation subscale** also showed a significant effect, $F(2, 44) = 6.18$, $p = .004$, $\eta_p^2 = 0.22$ (Figure 1c). Bonferroni-corrected post-hoc comparisons showed that the no-sound and music conditions differed significantly. Likewise, **total score** showed a significant effect, $F(2, 44) = 4.29$, $p = .020$, $\eta_p^2 = 0.16$ (Figure 1d). The post-hoc test confirmed a significant difference between the no-sound and music conditions.

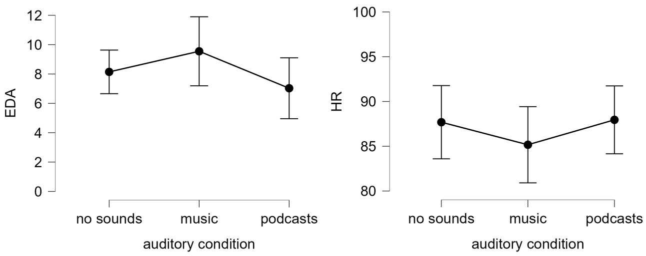
3.1.2 Qualitative insights. The qualitative data from the subsequent interviews with the participants confirm these results. Regarding subjective preference, 17 out of 23 participants stated that they preferred the ride with music. Five of these justified their answer in that the rides with music were "relaxing and pleasant" and five participants referred to "better immersion". Four participants preferred music because it served as a "distraction from the roller coaster experience", while one participant emphasized the dynamic nature of the music, noting that it built to a climax that matched the ride and had an appropriately matching duration. Two participants expressed a preference for music without providing a specific reason. Five participants preferred the ride with the podcast. Three of them found the podcast enjoyable, while two appreciated it as a distraction from the ride. In addition, one participant preferred the ride with no sounds, stating that it was easier to focus on the ride experience. Observations during VR roller coaster rides revealed noticeable head and body movements in 20 out of 23 participants. The participants actively leaned into the curves and frequently looked around the surroundings. Additionally, five participants had to take an extended break between VR rides because they still experienced VRS symptoms after the break interval.

3.2 Objective

EDA and **HR** scores were collected from 22 participants throughout the simulation. These were averaged over the duration of exposure and analyzed using a repeated-measures ANOVA. The acoustic condition had no significant effect on the EDA, $F(2,42) = 1.72$, $p = .192$, $\eta_p^2 = 0.08$ (Figure 2a), or the HR, $F(2,42) = 0.62$, $p = .542$, $\eta_p^2 = 0.03$ (Figure 2b).

4 Discussion

The present study aimed at evaluating the impact of different auditory contexts on VRS development by comparing SSQ scores, qualitative feedback and physiological responses across three conditions: no sounds, music, and podcasts.



(a) EDA **(b) HR**

Figure 2: Effect of different auditory conditions on the mean values of EDA and HR. Error bars indicate 95% confidence intervals.

Subjective data show that auditory conditions can influence VRS. There was a significant decrease for the music condition on oculomotor, disorientation, and the SSQ total score, providing support for ***H1***. Pairwise comparisons showed that music significantly outperformed podcasts on the oculomotor subscale and no sounds on disorientation and total SSQ scores. In contrast to the study of Kourtesis et al. [17], there was no significant effect on the nausea subscale. However, Kourtesis et al. [17] also reported a substantial decrease in the total score, confirming that the music condition significantly outperformed the no-sound condition. Our findings are consistent with Keshavarz and Hecht [16], suggesting that music may serve as a pleasant distraction. The genre itself appears less relevant than the subjective pleasantness of the music, aligning with Peck et al. [27, 2354], who state that "music was most effective ... when it was self-selected and liked most by the participants." Their findings emphasize that music preference, rather than musical characteristics such as valence or arousal, plays a decisive role in reducing VIMS. Previous research from related fields supports this. Studies have shown that self-selected music can reduce self-reported anxiety and stress, enhance relaxation [8, 9, 18], and even increase pain tolerance and perceived control in a situation [24]. Familiarity with the music may promote emotional engagement and facilitate attentional shifts through personal associations and memories [12, 24, 28]. In a VR context, familiarity with self-selected music is likely to enhance emotional immersion and redirect attention toward positive associations, thereby mitigating the sensory conflicts that underlie VRS.

H2 predicted a reduction of VRS when listening to podcasts compared to a no-sound condition. The podcast condition could not be shown to significantly reduce VRS. For nausea, the podcast condition yielded a mean value, which was descriptively lower than the no-sound condition but higher than the music condition. A similar pattern emerged for disorientation, where the podcast condition again provoked sickness ratings which were lower than in the no-sound condition, yet higher than in the music condition. While these descriptive trends might suggest a possible alleviating effect of podcasts on some VRS symptoms, no significant differences were found in any SSQ subscale. Therefore, we cannot conclude that podcasts reduce VRS. Regarding oculomotor discomfort, the podcast condition was comparable to the no-sound condition. This finding contradicts Pöhlmann et al. [29], who observed a significant effect of cognitive demand on motion sickness. The cognitive demand imposed on the participant by processing the verbally spoken content in the podcast episode did not distract from VRS.

H3 suggested that there is no difference in sickness between the music and podcast conditions. This can be rejected, as music significantly outperformed podcasts on the oculomotor subscale. Although not all pairwise comparisons reached significance, there was a consistent trend in favor of the music condition on each SSQ subscale. One possible explanation is that music, especially when perceived as pleasant and self-selected, induces an immediate emotional response [20, 27], whereas podcasts require sustained attention, which may not be achieved within short durations of exposure.

The majority of the participants preferred the music condition, citing reasons such as pleasantness, relaxation, and immersion. This preference aligns with the significant reductions of VRS in the music condition. One reason for the perceived better immersion through music could be the similar duration of the chosen song to the length of the roller coaster ride. The median for the length of all songs that were listened to by the participants is three minutes and eight seconds. This means that the dynamic, climax and the ending of the song was approximately comparable to the roller coaster ride. However, in the short ride, podcasts did not reach a climax or an end. Only five participants preferred the ride with the podcast condition, citing reasons such as entertainment and diversion from the ride. Despite the growing popularity of podcasts [10, 25], there are large differences in the familiarity of participants with these auditory formats. Music is widely integrated into daily life, such as during commuting or driving, where it can be used for entertainment and mood regulation, while listening to podcasts remains less common in these contexts [11, 26]. This difference in familiarity may have contributed to the insignificant effect of podcasts in reducing VRS. The observed physical behaviors, such as leaning into curves, suggest a high level of presence and immersion in the VR environment. This can be a double-edged sword. While it indicates a successful VR experience, it can also contribute to VRS. This is confirmed by the five participants who needed an extended break between VR rides. A study of Stanney et al. [33] reported increased nausea symptoms in combination with increased presence scores. Another study of Martirosov et al. [22] demonstrated increased VRS symptoms in fully immersive environments compared to low and semi-immersive environments. These findings suggest a correlation between greater immersion and increased VRS scores.

The analysis of the physiological measurements EDA and HR showed no significant differences between the three auditory conditions. This lack of significant differences in physiological measures between conditions requires careful interpretation. Increases in EDA and HR may be driven by factors other than VRS, such as emotional arousal or stress during initial engagement with the VR environment [5, 21]. Given the relatively short exposure duration and that participants had just been seated in an unfamiliar immersive environment, initial arousal levels may have contributed significantly to the observed physiological responses, masking any subtle differences directly attributable to auditory conditions. Furthermore, the observed effects may have been too modest in relation to the inherent noise in the data. In short exposure scenarios, temporary fluctuations in physiological signals occur as participants adapt to the VR environment. Analyzing only mean values could mask these dynamic changes that are critical to understanding the interaction between auditory stimulus and physiological arousal. The potential limitations in data accuracy of the Empatica E4 device may have further diluted the ability to detect significant differences between conditions. The not VR-related study of Bosshard et al. [4] found significantly higher HR during music streaming compared to podcast formats, thus significantly influencing physiological responses. In contrast to our results, which showed no significant differences, their findings suggest that auditory content itself can cause different levels of physiological arousal. This divergence could be due to differences in exposure duration, familiarity of the participants, or the different environment in our study.

4.1 Limitations and Outlook

The within-subjects design, although effective in controlling for inter-individual variability, carries the risk of carry-over effects. Participants experienced all auditory conditions consecutively, with only short breaks in between, which may have increased VRS symptoms in subsequent trials. A between-subjects design or scheduling sessions on different days would have provided a more consistent alternative, but such approaches were deemed impractical due to resource constraints of this study. Although order randomization was used to counterbalance the order of the different auditory conditions, repeating the same VR simulation three times may have induced anticipation or habituation effects, thus confounding subjective and physiological responses. The small sample size limits the statistical power of the study. It is conceivable that some of the non-significant trends observed might have reached significance with a larger participant pool. The reliance on a student sample, primarily consisting of young adults, further constrains the generalizability of the findings to more diverse populations.

Future research should adapt a multi-day within-subjects design to reduce potential carry-over and anticipation effects. Increasing the sample size and including a more demographically diverse participant pool would enhance the statistical power and generalizability of the findings. Further studies should investigate the reason for music alleviating VRS. In particular, the roles of emotional engagement, familiarity, and attentional distraction. Understanding why self-selected, familiar music proves more effective than semantically rich and unfamiliar content such as podcasts remains an open question. In addition, future work could explore whether the observed benefits of music are primarily attributable to its soothing qualities or to individual preference. To further improve comfort during intense movement, the effectiveness of self-selected music in more dynamic, motion-intensive VR simulations could be further investigated.

5 Conclusion

The present study shows that music can mitigate subjectively perceived VR-induced sickness, particularly symptoms related to oculomotor disturbances and disorientation. However, a positive effect of listening to a podcast during the simulation could not be demonstrated, as it had only a descriptively small effect on VRS. Future research should explore the causal factors of the positive effect of music, as well as examine additional environmental factors that may contribute to user comfort. Our findings contribute to improving VR applications by reducing motion sickness and increasing user comfort, which may benefit applications in entertainment, training, and therapy. Based on our results, the integration of self-selected music may serve as an effective and low-effort strategy to alleviate VRS in virtual environments.

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The SDC approach was applied for the sequence of authors.

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A Study Design

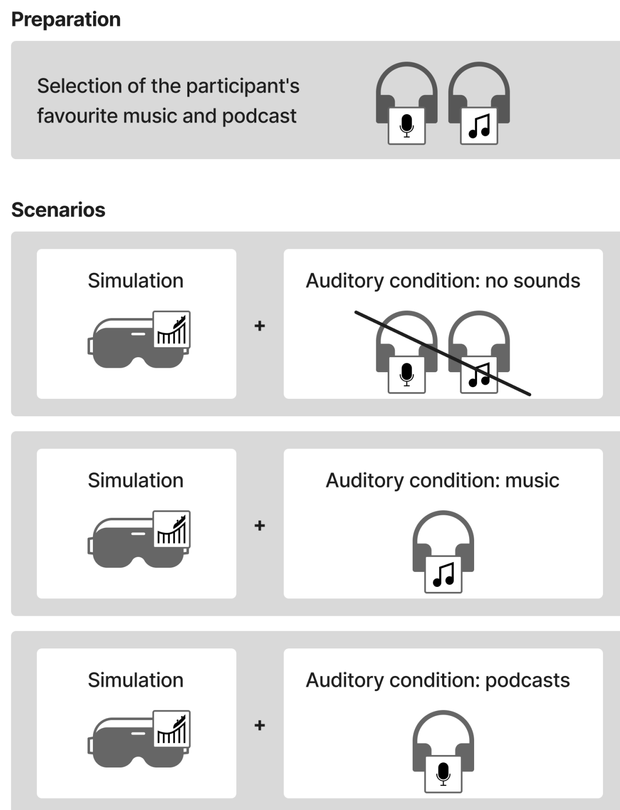

Figure A.1: Illustration of the experimental procedure. In the preparation phase, a selection of preferred music and podcasts was made. During the simulation phase, each participant experienced three scenarios with different auditory conditions: no sounds, music, and podcasts.