

With a Little Help From My Playlists: The Impact of Background Music on Sustained Attention Performance

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A long line of research has investigated vigilance decrement, the decline in the sustained attention performance over time. Overload perspectives suggest this decrement results from cognitive resource depletion because of task load, while underload perspectives attribute it to attention disengagement from tasks that are inherently underarousing and monotonous. Based on these two perspectives, this article investigates whether background music influences arousal and task load, thereby affecting vigilance performance. Across two experiments that were conducted in 2023 and 2024, we systematically examined the effects of music presence and different types of music (liked, disliked) on performance during an abbreviated and visually taxing vigilance task. We analyzed the roles of arousal, boredom, task load, task engagement, and personality traits (extraversion, boredom proneness). Our results did not fully align with either the overload or underload perspectives. We discuss these findings within alternative theoretical frameworks, offering new insights into the complex dynamics of vigilance and attention.

Public Significance Statement

People often find it hard to stay focused on tasks for long periods. Traditional theories do not satisfactorily explain how attention works over time and they might benefit from integrating insights from boredom research. Our research suggests that listening to music does not meaningfully impact attention performance. However, music enhances alertness and engagement while reducing boredom. This combination might help maintain motivation and improve performance in the long run.

Keywords: vigilance decrement, sustained attention, boredom, arousal

Why do we sometimes listen to music while working on a task, but any type of background noise becomes distracting at other times? Why do some people work most efficiently in the presence of music or background noise, but others need complete silence? The question of whether music impacts performance has been raised repeatedly over the years (Dalton & Behm, 2008; Kämpfe et al., 2011; Mendes et al., 2021; Schwartz et al., 2017; Szalma & Hancock, 2011). The answer to it, however, has been mixed, since a large array of studies have revealed that music can have either beneficial, detrimental, or null effects on cognitive performance and attention (Küssner, 2017; Mendes et al., 2021). The debate has its roots in the vigilance research, which has been dominated by overload theories which argue that the cognitive capacity is a finite resource that gets

depleted after use. This theory has been challenged mainly by underload theories, which argue that the testing conditions are dull and increasingly boring. Although both overload theories and underload theories have been tested repeatedly, we contend that there is a general conflation between the constructs of arousal and boredom, which leads to further unresolved questions. Accordingly, we would like to contribute to the ongoing discussion and put both views (i.e., overload and underload theories) to test by revisiting and distinguishing boredom and arousal. It is our goal to understand whether and how music can affect sustained attention performance through influencing arousal and task load. To this end, we examine the effects of background music and different music types on vigilance performance across two studies. We investigate whether arousal mediates this

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effect, and if so, whether certain personality traits (i.e., extraversion, boredom proneness) moderate this relationship. Finally, we explore the ways in which task load, boredom, task engagement, fatigue, and task perception are related to vigilance.

Vigilance Decrement

Vigilance is the ability to remain alert to the irregular and unpredictable changes or signals in the environment. Vigilance literature began to receive attention in the late 1940s with Mackworth's experiments. Mackworth observed that, when participants were required to detect an irregular target during a continuous display of nontargets over a few hours, reaction times consistently decreased, and the error rates increased within the first 20–30 min (Mackworth, 1948). This decrease in signal detection has been replicated in various experimental designs (e.g., different modalities, frequency of the target), and it has been termed vigilance decrement (Eysenck, 1988; Mackworth, 1948; See et al., 1995).

The Two Theories on Vigilance Decrement

Mainly, two theories have been put forward to explain the underlying mechanisms of vigilance decrement: overload and underload theories. These perspectives differ on whether the increased workload and the consequent performance drop are a direct or indirect result of the task requirements (Hitchcock et al., 1999).

Overload Theories

The overload theories are grounded in resource theory, which views cognitive capacity as a finite resource that depletes after activities requiring mental effort (Parasuraman et al., 1987). Overload theories posit that because of continuous exertion during vigilance tasks, available cognitive resources become depleted, leading to a performance decline over time. It is argued that vigilance tasks are demanding and require a high level of mental effort, as evidenced by reports of increased task load and stress (Hitchcock et al., 1999; Warm et al., 1996, 2008).

The overload perspective finds partial support in ego depletion research, which has been influential in shaping the resource model of self-control. Early studies suggested that when a task requiring high levels of self-control is followed by another task, performance in the subsequent task deteriorates, presumably because of depleted cognitive resources (Baumeister et al., 2018; Muraven & Baumeister, 2000). However, it is important to note that the ego depletion concept has become highly controversial, with several meta-analyses questioning its robustness and suggesting that the underlying mechanisms may be more complex than originally proposed (Carter et al., 2015; Hagger et al., 2016). Nevertheless, decreases in vigilance performance have been similarly interpreted as reflecting resource depletion and overall workload (Smit et al., 2004; Warm, 1993). Although the precise nature of this resource depletion process remains unclear (Matthews et al., 2000), resource theory continues to be widely used to explain vigilance findings (Helton et al., 1999, 2008; Temple et al., 2000; Warm et al., 1996).

Underload Theories

While overload theories are relatively well-defined, theories addressing underload remain conceptually dispersed and lack a

singular, unified framework. This section aims to highlight this theoretical ambiguity by outlining several perspectives and demonstrating the varied ways in which underload has been conceptualized. Underload perspectives, such as the mindlessness hypothesis, mind-wandering hypothesis, and the goal habituation theory (Ariga & Lleras, 2011; Robertson et al., 1997; Smallwood & Schooler, 2006), suggest that the decrease in performance is because of the underarousing nature of vigilance tasks. For instance, the mindlessness theory and the goal habituation theory argue that the mechanisms underlying sustained attention diminish in activation over time (Ariga & Lleras, 2011; Robertson et al., 1997). A typical vigilance task lasts a couple of hours, although performance decrement has also been observed in shorter versions (e.g., 12 min; Temple et al., 1997). In these tasks, the target appears infrequently and requires an action, while the nontargets appear frequently and do not require an action. Therefore, it is argued that the task requirements are constrained and repetitive. Due to this limited nature of the task, the mindlessness and the goal habituation theories argue that the task load is underarousing, and that this insufficiency causes attention to disengage from the task, leading to monitoring becoming "mindless" (Manly et al., 1999; Robertson et al., 1997). In the sustained attention to response task (SART), Robertson et al. (1997) modified the traditional vigilance task to its "opposite," requiring participants to respond to frequent nontargets and withhold their responses to the target. They found that commission errors in the SART were predicted by participants' self-reports of absentmindedness, indicating a decoupling of attention. This finding was supported by the results of Smallwood et al. (2004), who discovered that task-unrelated thoughts correlated with attentional lapses in the SART. However, the SART itself induces boredom (Hunter & Eastwood, 2018), which complicates the relationship between vigilance performance and boredom.

Like the mindlessness theory, the goal habituation theory (Ariga & Lleras, 2011) posits that vigilance decrement occurs because attention becomes disengaged from the task over time. This theory suggests that, like the perceptual systems or complex representations that show habituation effects, the cognitive control system also fails to sustain attentional goals with time on task because of habituation effects. In their study, Ariga and Lleras (2011) temporarily deactivated the goal representation during the vigilance task and reactivated it by switching to a memory retrieval task several times during a 40-min vigil. They found that goal activation was strengthened, as no performance decrement was observed. However, the goal habituation theory did not receive support in studies that varied task duration and difficulty (Helton & Russell, 2013).

Similarly, the mind-wandering hypothesis argues that attention becomes disengaged from the task and instead engages in task-unrelated thoughts, or mind-wandering (Smallwood & Schooler, 2006). It posits that both mind-wandering and the primary vigilance task draw upon the same attentional resources. Consequently, the decoupling of attention from the task and the preoccupation with task-unrelated thoughts deplete these resources, indirectly causing vigilance deterioration (Schooler et al., 2011; Smallwood, 2010). While the strongest evidence supporting the resource theory is the correlation between task difficulty and vigilance decrement (Helton & Russell, 2013; Helton & Warm, 2008), this relationship is indeed compatible with the mind-wandering hypothesis as well (Smallwood & Schooler, 2006; Thomson et al., 2015).

Overall, underload theories argue that attention disengages from the task, and participants must combat the resultant boredom or

low arousal caused by the understimulating and simplistic nature of these tasks. In contrast to overload perspectives, which interpret high workload reports as direct evidence of the task's demanding nature, underload theories posit that increased workload is an indirect result of efforts to resist growing boredom and maintain attention on the task (Alikonis et al., 2002). Reduced arousal levels are further evidenced by participants' reports of task boredom and monotony (Scerbo, 1998; Scerbo et al., 1992), as well as in reports of increased fatigue (Galinsky et al., 1993).

Arousal and Music

While both task load and arousal have been proposed as mechanisms contributing to performance decrement, the following discussion will primarily focus on the role of arousal, particularly in relation to music. It is generally observed that arousal decreases during vigilance tasks (Meuter et al., 2005). For instance, Pattyn et al. (2008) found that heart rate and respiration declined throughout the vigilance task, which they interpreted as evidence of decreasing arousal levels and the underlying cause of vigilance deterioration. These time-on-task effects are also evident in reduced neural activity (Breckel et al., 2011) and increased alpha and beta powers, suggesting decreasing arousal and increasing effort to remain alert (Boksem et al., 2005). When overall arousal levels are low, performance deteriorates; conversely, preventing arousal levels from decreasing either maintains or improves performance compared to low-arousal conditions (Corcoran, 1965).

While we reference findings related to both music and noise, our primary aim in this article is to examine how music, which is structured and emotionally meaningful auditory stimulus, affects sustained attention. Although both music and nonmusic background noises represent auditory stimuli, they differ substantially in terms of their structure and psychological effects (Nadon et al., 2021; Pascoe et al., 2022; Reybrouck et al., 2019). Music typically consists of organized, intentional sound patterns that can evoke emotional and cognitive responses through features such as tempo, familiarity, and valence (Antony et al., 2018; Umemura & Honda, 1998). In contrast, noise is generally chaotic, nonstructured, and often associated with distraction and disruption (Banbury & Berry, 1998; Lindgren & Axelsson, 1983). Owing to these fundamental differences, we treat music and noise as conceptually and functionally distinct. While we briefly reference findings related to background noise to provide context for prior work on auditory distraction, as its effects in simple vigilance tasks remain debated (Dalton & Behm, 2008), our focus is squarely on music, particularly music that is liked, familiar, and fast in tempo, because of its ability to influence arousal, engagement, and attentional processes as discussed below.

In the context of background music and sustained attention, the role of arousal has been widely studied. Arousal, a key factor in maintaining attention, can be influenced by internal and external stimuli (Humphreys & Revelle, 1984). Music is frequently used in the literature as a tool to manipulate arousal because of its noninvasiveness, accessibility, and potential to reduce boredom and enhance mood (Alikonis et al., 2002; Lonsdale & North, 2011; Rickard, 2004; Schwartz et al., 2017). Despite extensive research, findings on music's effect on vigilance performance remain mixed (Küssner, 2017; Mendes et al., 2021).

The Role of Background Music in Sustained Attention

Some studies suggest that background music can impair sustained attention. For example, Alikonis et al. (2002) found that the presence

of calming music reduced boredom but also resulted in poorer performance on signal detection tasks compared to silence and nonmusic background noise conditions. Similarly, Umemura et al. (1992) reported that music had a detrimental effect on attention, while Cassidy and MacDonald (2007) found that music impaired performance relative to a silent condition. These results indicate that music may interfere with performance in vigilance tasks.

However, other research has suggested no significant effects of background music on sustained attention. Kiss and Linnell (2021), for instance, found that self-chosen music increased subjective focus but did not affect performance in a low-demand task. Similarly, Burkhard et al. (2018) found that although music increased arousal, it did not significantly affect task performance. These studies imply that while music may influence the subjective experience, its effect on actual performance may be negligible under certain conditions, particularly when the task is relatively undemanding.

In contrast, other evidence supports the idea that music can enhance sustained attention. Davies et al. (1973) reported that music improved detection rates and reduced performance deterioration in more demanding vigilance tasks. More recent work by Kiss and Linnell (2024) and Kiss et al. (2024) suggests that preferred music reduces mind-wandering and improves task focus, which may help sustain attention over time. These findings indicate that music, especially when liked or familiar, can promote sustained attention by enhancing task engagement.

Music Characteristics and Preference

Although earlier studies primarily examined the presence or absence of music, more recent research emphasizes the importance of specific musical characteristics. Mendes et al. (2021) highlighted that rhythm, emotional valence, and familiarity of the music can significantly influence attention. In relatively simple tasks, relaxing or familiar music may enhance performance by reducing mind-wandering and improving accuracy and reaction times (Feng & Bidelman, 2015; Fontaine & Schwalm, 1979; Fox, 1971; Oldham et al., 1995). However, in more complex tasks, highly arousing or unfamiliar music may be detrimental (Beh & Hirst, 1999; McGrath, 1965; North & Hargreaves, 1999). For example, Corhan and Gounard (1976) found that energetic music such as rock may improve performance in vigilance tasks, especially when compared to more relaxing instrumental music. These findings suggest that the cognitive impact of music depends heavily on its specific properties.

Preference for music also plays a crucial role in determining its influence on task performance. Recent research has shown that liked or preferred music reduces mind-wandering and increases focus during low-demand tasks (Kiss & Linnell, 2021). Similarly, Baldwin and Lewis (2017) examined the effect of listening to different types of music during breaks between sets of the SART and found that performance, as measured during the task following the break, was improved by liked music and impaired by disliked music. In earlier work, Davies et al. (1973) did not explicitly control for preference, however, they noted that music improved vigilance performance in the more difficult version of their task and acknowledged that some participants reported disliking the music. Finally, Huang and Shih (2011) showed that as the dislike for music increased, attention performance declined. Together, these findings suggest that music preference can influence whether music acts as a cognitive aid or a distraction.

Johansson et al. (2012) compared preferred and nonpreferred music to background café noise and found that nonpreferred music negatively affected performance, while noise had no impact. This implies that disliked music, although still structured, may function similarly to noise in terms of its attentional effects. Considering that nonmusic background noise often impairs attention (Dalton & Behm, 2008; Wokoun, 1963), it is plausible that disliked music may be comparably disruptive because of its negative valence and reduced emotional alignment with the listener. However, given the limited research on disliked music, further investigation is necessary.

Music and the Theoretical Frameworks

The few studies that have examined the effects of music and nonmusic background noise through the lenses of underload and overload theories have reached mixed conclusions. Smit et al. (2004), for instance, introduced irrelevant stimuli (e.g., gray squares and auditory tones) during a vigilance task. According to arousal theory, these irrelevant stimuli (gray squares and tones at 1,500 and 1,530 Hz) were expected to reduce task monotony and improve performance. Conversely, according to resource theory, these stimuli were expected to have either a neutral or negative effect if the stimuli were ignored. Their findings supported resource theory, showing no performance benefit from the added stimuli.

Conversely, Becker et al. (1995) found that nonmusic background noise impaired performance. Consistent with resource theory, they suggested that participants had to “expend processing resources to combat the detrimental effects of noise” (p. 58), which further depleted their available resources and worsened performance. Similarly, North and Hargreaves (1999) investigated the combined effects of task load and music arousal on driving performance. Participants performed more slowly when exposed to highly arousing music and a backward-counting task compared to unarousing music and no backward-counting task. North and Hargreaves argued that if an arousal-based explanation were correct, music would have improved performance. However, in line with resource theory, they found that music reduced the cognitive resources allocated to task performance even in very simple tasks.

It is unclear how overload perspectives would precisely account for these contradictory findings. It is possible that stimuli of varying disruptive levels have different effects on cognitive resources and performance. For example, interruptions that require attention as part of a secondary task are more detrimental to working memory than task-irrelevant distractions (Clapp & Gazzaley, 2012). We speculate that background music, particularly music with emotional valence (liked and familiar), may be more personally relevant and thus more challenging to ignore compared to simple tones, squares, or jet engines (Becker et al., 1995; Smit et al., 2004).

While underload and overload theories may seem at odds, we propose that they are not necessarily mutually exclusive. Their relevance likely depends on task complexity and individual differences. For example, in simpler tasks, where the risk of understimulation and boredom is higher, background music may serve to increase arousal and engagement, consistent with underload theory. In more complex, attention-demanding tasks, the cognitive effort required to process background music may compete with task-related resources, leading to performance declines as predicted by overload theory. In other words, background music may have differential effects depending on the complexity of the task, with the nature of the task influencing

whether the music serves to increase arousal and improve engagement (underload) or depletes cognitive resources (overload). This nuanced understanding leads us to expect that background music can have varying effects on sustained attention performance, depending on task context and individual differences. In this sense, the effects of music on sustained attention are context-dependent, shaped by both the context and the individual’s characteristics. Although the vigilance literature reports mixed findings, there is general consensus that music increases arousal, task engagement, and focus. We therefore expect that any direct effect of music on performance will be mediated by its ability to increase arousal. Thus, we anticipate that:

Hypothesis 1 (H1): People who listen to music that is liked, familiar, and fast tempo during a sustained attention task would perform better than those who do not listen to any music.

Hypothesis 2 (H2): Arousal would mediate the effect of background music on sustained attention.

Baldwin and Lewis’s (2017) study examined the effect of listening to different types of music during breaks but not during the task itself. Therefore, the observed effect could reflect restored and replenished cognitive resources or alleviated task-related boredom. We aim to contribute to the ongoing investigations by expanding upon Baldwin and Lewis’s study, specifically by comparing the effects of listening to liked and disliked music during a visual vigilance task. While we are unaware of any studies that focus on the liking of background music, research on the effects of task-irrelevant emotional stimuli might be relevant. Such stimuli can have direct effects (by engaging attention) or indirect effects (by prompting task-irrelevant thoughts), both competing for cognitive resources during the task (Flood et al., 2015). Generally, the presence of negative stimuli is associated with poorer attention performance. Being exposed to negative words during a semantic vigilance task leads to poorer performance compared to neutral words (Zsidó et al., 2024). Similarly, exposure to negative, task-irrelevant images deteriorates performances compared to neutral images (Helton & Russell, 2011; Ossowski et al., 2011). Additionally, high-arousal negative distractors are associated with worse task-related attention compared to positive or neutral distractors (Sussman et al., 2013). From an overload perspective, we speculate that exposure to disliked music would deplete more cognitive resources than exposure to liked music. However, from the underload perspective, we do not have clear expectations regarding the differential effects of liked versus disliked music. We expect that,

Hypothesis 3a (H3a): People who listen to music that they like during a sustained attention task would perform better than those who listen to music that they dislike.

Hypothesis 3b (H3b): People who listen to music that they like during a sustained attention task would perform better than those who do not listen to music at all.

Personality Traits

Additionally, a substantial body of personality research has focused on investigating individual differences in vigilance performance (Finomore et al., 2009). Arousal levels can vary based on certain individual differences, which may moderate the performance.

Among others, extraversion and boredom proneness are relevant to optimal stimulation levels.

Extraversion

Arousal theory suggests that introvert individuals have higher levels of cortical arousal compared to extraverts (Eysenck, 1967; cited in Eysenck, 1988; Koelega, 1992) and suggests that “arousal facilitates the maintenance of attention over time” (Koelega, 1992, p. 239). It is assumed that introverts, being more aroused when engaged in a task, are better at sustaining attention compared to extraverts (Corcoran, 1965; Eysenck, 1988). A meta-analysis confirmed that introverts generally perform better than extraverts in vigilance tasks (Koelega, 1992). However, when external or internal sources of arousal, such as background music or caffeine, are introduced, the performance patterns can shift. For example, caffeine improves vigilance performance in extraverts, but not in introverts (Keister & McLaughlin, 1972). Additionally, extraverts benefit more from the arousal induced by secondary tasks compared to introverts, whose performance declines under similar conditions (Bakan, 1959). Although background noise improves extraverts’ performance, it does not influence introverts (Davies & Hockey, 1966). Similarly, Davies et al. (1969) observed that extraverts listening to radio and television broadcasts during a vigilance task performed better than those in a silent group, whereas no such effect was observed for introverts. In contrast, Daoussis and McKelvie (1986) found that introverts listening to music during a text comprehension task performed worse compared to a silent condition, while music had no effect on extraverts.

These findings highlight that the effects of stimulation are not uniform across personality types and highlight the importance of considering the context when evaluating performance outcomes. Rather than seeing extraverts and introverts as having inherently opposed needs, it would be more accurate to consider that both groups may respond differently to stimulation depending on the task context. For example, in simpler tasks that are likely to cause understimulation, background music may help engage both extraverts and introverts. Conversely, in more complex, demanding tasks, the additional cognitive load of processing music may hinder performance for both groups, depending on their individual characteristics and the complexity of the task. Accordingly, we hypothesized that:

Hypothesis 4 (H4): Individuals high in extraversion that listen to music during a vigilance task would perform better than those high in introversion that listen to music.

Boredom Proneness

Although it is thought that boredom has the most detrimental impact on overall vigilance performance (Wylie et al., 1985), proneness to get bored is rarely considered in the vigilance literature. Boredom proneness refers to the tendency to frequently experience intense feelings of boredom irrespective of situational characteristics (Farmer & Sundberg, 1986; Mercer-Lynn et al., 2014). Generally, individuals with higher levels of boredom proneness perform worse in vigilance tasks and report higher state boredom after the task compared to those with lower levels of boredom proneness (Sawin & Scerbo, 1995). Kass et al. (2001) found that boredom proneness

predicted performance in the initial 10 min of an hour-long vigilance task. Within the boredom literature, individuals who struggle with sustaining attention also report higher boredom proneness (Hunter & Eastwood, 2018; Isacescu et al., 2017; Malkovsky et al., 2012; Thackray et al., 1977).

There is limited research on how background noise affects the vigilance performance of individuals with high (vs. low) boredom proneness, as well as its impact on their boredom and arousal levels. Given that boredom-prone people report stronger boredom in vigilance tasks compared to those with lower levels in this trait (Sawin & Scerbo, 1995), it can be expected that music may provide the necessary stimulation that high boredom-prone individuals could benefit from during these tasks. However, as with extraversion, the effect of music may depend on the task context. In tasks where boredom is likely to be high, music may provide the necessary arousal to prevent disengagement. In contrast, more complex tasks might lead to cognitive overload because of the additional demands of processing background music, thus negating any benefits. Therefore, we expected that:

Hypothesis 5 (H5): High boredom-prone individuals that listen to music during a sustained task would perform better than low boredom-prone individuals that listen to music.

Overview of Studies

To test these hypotheses, we conducted two separate preregistered lab studies. The first study examined the impact of background music presence versus absence on sustained attention performance (H1). We anticipated that arousal would mediate the effect of music on performance (H2). We also hypothesized that specific personality traits (i.e., extraversion, boredom proneness) would moderate this mediation (H4 and H5).

In Study 2, we had three experimental groups to investigate whether listening to music of different valences (liked vs. disliked) influences vigilance performance compared to a silent situation. We tested H3a and H3b, predicting that listening to liked music would enhance performance more than disliked music or no music at all. Additionally, we explored differences in fatigue, task load, and task engagement across these conditions in relation to sustained attention.

Study 1

Method

Sample

An a priori power analysis was conducted using the online tool WebPower for the conditional model 58, which is based on the R package *pwr2ppl* (Zhang & Yuan, 2018).¹ The procedure calculates power through Monte Carlo simulation, based on model assumptions and sample size. To detect the smallest meaningful conditional effects in a moderated mediation model, we assumed correlations of, $r = .3$, between the variables and correlations of, $r = .2$, between the interactions and the mediator (Correll et al., 2020; Edwards & Lambert, 2007; Preacher et al., 2007; Xu et al., 2024). For the remaining model specifications, we adopted the default values.

¹ See <https://webpower.psychstat.org/models/modmed58/> for the model.

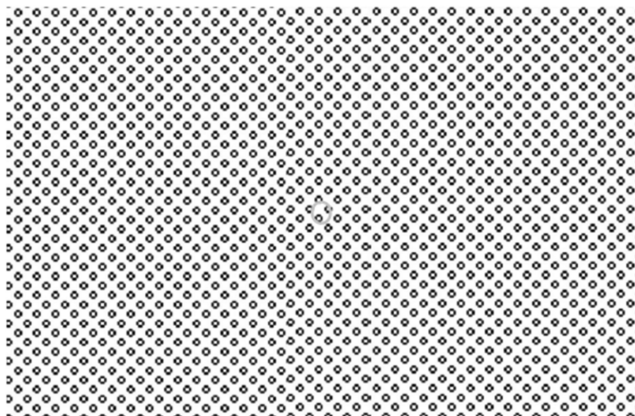
We started with a sample size of 100 participants and increased sample size by 10 participants until the calculated power reached at least 80% (Cohen, 1992). With a sample size of 120 participants a power of 81% for the conditional indirect effect was achieved. Accordingly, for this study, data were collected from 120 participants ($M = 22.3$ years, $SD = 4.65$, 68.3% female). Participants were undergraduate students and received partial course credit for their participation.

Materials

To measure trait boredom, we used the Short Boredom Proneness Scale (SBPS; Farmer & Sundberg, 1986; Struk et al., 2017). Eight items were rated on a 7-point scale (1 = *strongly disagree* to 7 = *strongly agree*; $\alpha = .79$). To measure extraversion, we used the NEO Five-Factor Inventory (Borkenau & Ostendorf, 1993; Costa & McCrae, 1989). Twelve items are rated on a 5-point scale (1 = *strongly disagree* to 5 = *strongly agree*; $\alpha = .60$). Higher values indicate stronger extraversion. We measured arousal using the self-assessment manikin on a 4-point scale (Bradley & Lang, 1994). It was measured once the practice trials were completed (pretask) and once more after the test trials were completed (posttask). Higher scores indicate higher arousal. To measure state boredom, we used a single item “I am feeling bored” from the Multidimensional Boredom Scale (MSBS; Fahlman et al., 2013). It was rated on a 7-point scale (1 = *I do not agree at all* to 7 = *I fully agree*). Participants in the music group indicated whether the songs they listened to were mostly familiar to them (*yes, unsure, or no*) and how much they liked the music (from 1 = *I did not like the music at all* to 5 = *I liked the music a lot*). Finally, using an affective slider adapted from Betella and Verschure (2016), participants indicated how the music made them feel on a scale (from 1 = *tired* to 100 = *wide awake*). We adapted the short version of the vigilance task used in Temple et al. (2000), which has been used repeatedly and was observed to result in vigilance decrement (Botella et al., 2001; Dillard et al., 2019). Participants were randomly shown either the target (“O”) or one of the two nontargets (“D” or “G”; see Figure 1). They were instructed to press the spacebar when the target was shown and to withhold their reaction when a nontarget was shown. The task was about 12 min long and consisted of 870 trials.

Figure 1

The Background and Target Used in the Vigilance Task



Of these, the target was shown in 174 trials. The signals were shown at a rate of 72.5 events/min. Each signal was shown for 590 ms. The task was programmed and run using Inquisit 6 (Inquisit, 2016).

Design and Procedure

Prior to the study, we conducted a pilot study to identify the most familiar and well-liked songs. The pilot study included 37 participants ($M = 23$ years, range 18–42 years) who listened to a total of 25 songs selected from the 2021 German charts (Offizielle Deutsche Charts, 2021). We selected songs from the 2021 charts to ensure familiarity without the songs being overplayed, which could lead to reduced interest. Participants rated each song for familiarity and liking on a 7-point Likert scale (1 = *I do not like this song at all* to 7 = *I like this song very much*). From this pool of 25 songs, only those that were both highly familiar and moderately liked by participants were selected for the final study. The four songs with the highest average ratings of familiarity and liking ($M > 5.0$ on the 7-point scale) were chosen for the main experiment: *Stay* by Justin Bieber and The Kid Laroi ($M = 5.51$), *Blinding Lights* by The Weeknd ($M = 5.32$), *Beggin* by Måneskin ($M = 5.14$), and *Heatwaves* by Glass Animals ($M = 5.11$). An additional, 1-min excerpt was created using the song ranked fifth in familiarity and liking, *I Wanna Be Your Slave* by Måneskin ($M = 5.05$), for use in the practice trials. These songs were compiled into a 12-min-long audio excerpt for the music group. All participants in the music group listened to the songs in the same order, ensuring consistency across all participants. The songs were selected for their moderate tempo and emotional engagement, typical of contemporary pop and rock genres, which have been shown to influence emotional arousal and attention.

Participants were tested in the computer lab of the university. They were randomly assigned to either the music group, who completed the sustained attention task while listening to the chosen music, or the control group, who completed the task without any background music. All participants were instructed to wear headphones.

The study began with participants answering trait boredom questions, followed by the vigilance task. After completing 1 min of practice trials, participants rated their arousal levels (pretask). This was followed by the test trials. The music group listened to music through headphones during both practice trials and test trials. We measured arousal after the practice trials and not during the vigilance task itself to not cause any interruption. The test trials consisted of a single uninterrupted block and did not have any breaks. After completing the test trials, all participants rated their arousal levels again (posttask arousal) and their state boredom (posttask boredom). Additionally, the music group answered music evaluation questions. Finally, all participants completed the extraversion scale and provided demographic information.

Transparency and Openness

This study was reviewed and approved by the Ethics Committee of the Department of Human-Centered Computing and Cognitive Science, University of Duisburg-Essen. The participants provided their informed consent to participate in this study. This study's design and hypothesis were preregistered (see <https://aspredicted.org/we68e.pdf>). The data were collected in 2022 and 2023. The data sets generated and analyzed for these studies are available at <https://osf.io/9rdpu/>.

Results

Our main dependent variables were the total number of correct answers in the vigilance task and pretask arousal ratings. Additionally, we measured commission errors (false alarms) and omission error rates. To analyze performance changes throughout the task, we split it into three intervals of equal length (T1, T2, T3), 4 min each. For each of these intervals we have determined performance separately. The latency of correct answers was also recorded, which are not reported here. All analyses were conducted on the jamovi software (V2.3) for macOS (The Jamovi Project, 2024).

Preliminary Analyses and Time Effects

We first ran bivariate correlations. Results indicated that the total number of correct answers was negatively related to extraversion, $r = -.18$, $p = .041$. There was a significant negative correlation between pretask arousal and commission errors, $r = -.18$, $p = .04$. In the music group ($N = 61$), music liking was positively related to the number of correct answers, $r = .26$, $p = .03$, and negatively related with commission errors, $r = -.28$, $p = .02$. For other correlations, see Table 1.

A mixed-factorial analysis of variance (ANOVA) was conducted to determine the effect of experimental group (between-subject factor) on the time changes in the omission error rates (within-subject factors) within the first 4 min of the task (T1), the second 4 min (T2), and the last 4 min (T3). There was no significant effect of group, $F(1, 118) = 0.62$, $p = .43$, $\eta_p^2 = .005$. However, there was a significant main effect of time, $F(2, 236) = 53.91$, $p < .001$, $\eta_p^2 = .314$. Following this, Tukey's honestly significant difference post hoc test was conducted to explore the differences in the error rates across time. Omission error rates at T1, $M = 0.11$, $SE = 0.00$, were lower than the error rates at T2, $M = 0.18$, $SE = 0.00$, $p < .001$, and T3, $M = 0.20$, $SE = 0.01$, $p < .001$. In turn, error rates at T2 were significantly lower than those at T3, $p < .016$. There was no significant interaction, $F(2, 236) = 0.06$, $p = .93$, $\eta_p^2 = .001$.

Arousal Ratings and Boredom Ratings

An independent samples t test showed that pretask arousal ratings were significantly different between the two groups, $t(118) = 2.43$, $p = .017$, $d = 0.44$; with the music group reporting higher arousal, $M = 2.36$, $SD = 0.83$, than the control group, $M = 2.00$, $SD = 0.78$. There were significant differences in the posttask arousal ratings, $t(118) = 4.41$, $p < .001$, $d = .80$; with the music group

reporting higher arousal, $M = 2.41$, $SD = 0.82$, than the control group, $M = 1.73$, $SD = 0.86$. Additionally, the music group reported significantly lower levels of posttask boredom, $M = 3.70$, $SD = 1.55$, than the control group, $M = 5.42$, $SD = 1.54$, $t(118) = -6.08$, $p < .001$, $d = -1.11$.

Hypothesis Testing

H1 predicted that participants who listened to music during the vigilance task would perform better than those who did not. As shown in Figure 2, independent samples t tests showed that there were no differences in the number of correct answers in the music group, $M = 146.16$, $SD = 24.05$, and the control group, $M = 142.88$, $SD = 22.63$, $t(118) = 0.76$, $p = .443$, $d = 0.14$. In terms of commission errors there was no difference between the music group, $M = 6.00$, $SD = 5.09$, and the control group, $M = 6.93$, $SD = 6.02$, $t(118) = -0.91$, $p = .361$, $d = -0.16$. Additional Bayesian independent samples t test indicated that, for the total correct answers, the Bayes factor (BF_{10}) was .254, and for the commission errors, BF_{10} was .284, indicating supportive evidence for the null hypothesis.

H2 predicted that arousal would mediate the effect of music on performance, and H4 and H5 predicted that personality traits (extraversion, boredom proneness) would moderate this relationship. We conducted two moderated mediation analyses: one with extraversion as the moderator and another with boredom proneness as the moderator. In the first model, the predictor variable was the experimental group, the mediator was pretask arousal, the dependent variable was total correct answers, and the moderator was extraversion. The model explained 5% of the variance in correct answers, $R^2 = .05$, $p = .288$. Extraversion did not moderate the effect of group on pretask arousal, $b = 0.01$, $z = 0.51$, $p = .60$. The interaction between extraversion and pretask arousal on correct answers was not significant, $b = 0.19$, $z = 0.38$, $p = .66$; nor did extraversion moderate the effect of group on correct answers, $b = 0.33$, $z = 0.38$, $p = .70$. In the second model the predictor, mediator, and dependent variables were the same as in the first model, and boredom proneness was the moderator variable. The model explained 5% of the variance in correct answers, $R^2 = .05$, $p = .113$. Boredom proneness did not moderate the effect of group on pretask arousal, $b = 0.08$, $z = 0.55$, $p = .57$. The interaction term between boredom proneness and pretask arousal on correct answers was significant, $b = -5.79$, $z = -2.38$, $p = .01$. However, boredom proneness did not moderate the effect of group on correct answers, $b = 0.54$, $z = 0.12$, $p = .90$. Thus, H2, H4, and H5 were rejected.

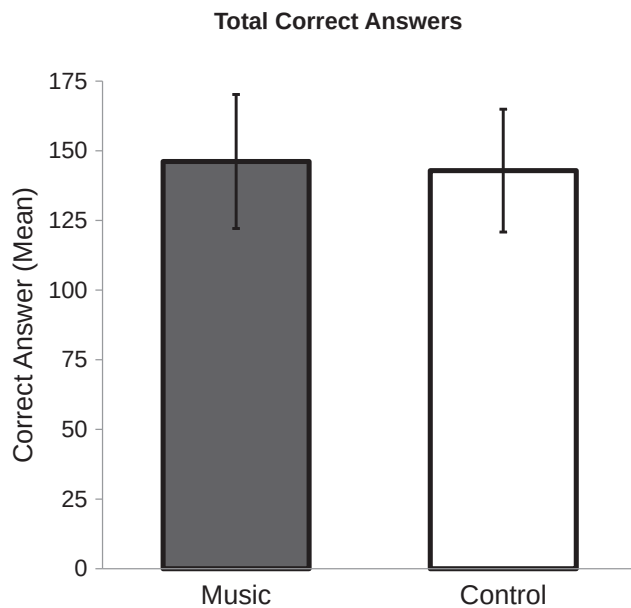
Table 1
Bivariate Correlations in Study 1

Variable	1	2	3	4	5	6	7	8
1. Total correct answers	—							
2. Commission errors	-.58***	—						
3. Arousal (pretask)	.07	-.18*	—					
4. Arousal (posttask)	.04	-.11	.27**	—				
5. Posttask boredom	-.04	.14	-.28**	-.65***	—			
6. Trait boredom	-.00	-.03	.06	-.08	.12	—		
7. Extraversion	-.18*	-.07	.05	.16	-.22*	-.27**	—	
8. Music liking ($N = 61$)	.26*	-.28	-.03	.11	-.24†	.08	-.00	—
9. Music arousal ($N = 61$)	-.20	-.06	.09	.32*	-.49***	.03	.30*	.44***

† $p = .05$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Figure 2

Mean Number of Correct Responses in Study 1 (Music vs. Control Groups)



Note. Error bars represent standard errors.

Exploratory Analyses

After observing differences in posttask boredom ratings between the two groups, we investigated whether these differences might explain any variations in the vigilance performance. We conducted two separate mediation analyses. In the first mediation, the predictor variable was the experimental group, the outcome variable was total the correct answers, and the mediator was posttask boredom. There was no direct effect of group on correct answers, $b = -2.93$, 95% confidence interval (CI) $[-12.43, 6.57]$, $z = -0.60$, $p = .54$. However, the group predicted posttask boredom, $b = 1.72$, 95% CI $[1.17, 2.27]$, $z = 6.08$, $p < .001$, $R^2 = .23$. Posttask boredom did not predict total correct answers, $b = -0.20$, 95% CI $[-2.90, 2.49]$, $z = -0.14$, $p = .88$; indirect effect $= -0.35$, 95% CI $[-4.99, 4.29]$. In the second mediation model, the predictor variable and the mediator were the same as in the first model, and the outcome variable was the commission errors. The group had no direct effect on commission errors, $b = 0.21$, 95% CI $[-2.03, 2.47]$, $z = 0.19$, $p = .85$. The group predicted posttask boredom, $b = 1.72$, 95% CI $[-1.69, 1.17]$, $z = 6.08$, $p < .001$, $R^2 = .23$. Posttask boredom did not predict the number of commission errors, $b = 0.41$, 95% CI $[-0.22, 1.05]$, $z = 1.27$, $p = .20$, indirect effect $= 0.71$, 95% CI $[-0.40, 1.84]$.

Discussion

Study 1 examined whether background music improves sustained attention performance by increasing arousal. We also investigated the role of specific personality traits (i.e., boredom proneness, extraversion) in this relationship. While listening to music heightened participants' arousal levels and reduced boredom compared to the control group, it did not influence performance. Participants in the music group reported higher arousal levels in both pre- and posttask

measurements, demonstrating that music effectively increased arousal, even during the practice trials. Furthermore, pretask arousal was negatively correlated with commission errors but not with correct answers. These findings align with previous research suggesting that while music enhances arousal during vigilance tasks, it most likely does not influence accuracy or error rates (Burkhard et al., 2018).

We also expected that extraverts and boredom-prone individuals would benefit from music-induced arousal, improving performance. However, our findings did not support this. Although introverts had more correct answers, neither extraversion nor boredom proneness moderated the relationship between arousal and performance. This outcome was unexpected, as we initially hypothesized that boredom proneness would influence how arousal from music affected task performance. However, the data showed no significant relationship between trait boredom and arousal (see Table 1), leading us to reconsider the role of personality traits in our experimental design.

Given this result, we decided to shift the focus of Study 2 to immediate and controllable factors, such as music preference, which could influence both arousal and task engagement. We hypothesized that listening to liked or disliked music would have a stronger impact on performance compared to personality traits, as it directly affects arousal levels and task engagement. This change allowed us to explore factors more directly tied to task performance.

While it is possible that the posttask boredom ratings could be influenced by the relief of task completion, the significant difference between the music and control groups suggests that music influenced participants' perception of the task. Specifically, the music group reported lower levels of boredom compared to the control group, indicating that music may have helped mitigate feelings of boredom during the task, regardless of the relief associated with completing the task. This difference in boredom ratings adds an important layer to understanding how music can affect the subjective experience of the task, even if it did not translate to improved performance.

Study 2

Method

Sample

The results of a power analysis using G*Power indicated that the required sample size to achieve 80% power for detecting an effect size of $f = .25$, at a significance criterion of $\alpha = .05$, was $N = 159$ for a one-way ANOVA. Thus, in Study 2, data were collected from 161 participants ($M = 24.1$ years, $SD = 6.95$, 72.7% female). In addition to two outliers and one participant who made no responses during the vigilance task (as preregistered), we excluded 41 participants who had previously taken part in Study 1. This overlap was identified post hoc during data screening. The final data set comprised 117 participants ($M = 24.9$ years, $SD = 7.78$, 68.4% female), which remained within the acceptable power range determined a priori.

Materials

To measure trait boredom, the SBPS was used ($\alpha = .83$; Farmer & Sundberg, 1986; Struk et al., 2017). State boredom (posttask boredom) was measured using the single item from the MSBS (Fahlman et al., 2013). Regarding task characteristics, participants

reported how interesting or boring (from 1 = *very interesting* to 5 = *very boring*) and how difficult or easy (from 1 = *very difficult* to 5 = *very easy*) the task was. Participants in the music groups indicated whether they were familiar with the music they listened to and how much they liked it. The same vigilance task from Study 1 was used.

Exploratively, we measured the mental task load using the NASA task load index (NASA-TLX; Hart & Staveland, 1988). This widely used tool consists of six subscales that assess the perceived difficulty experienced during the task. The subscales measure mental demand ("How much mental and perceptual activity was required? Was the task easy or demanding, simple or complex?"), physical demand ("How much physical activity was required? Was the task easy or demanding, slack, or strenuous?"), temporal demand ("How much time pressure did you feel because of the pace at which the tasks or task elements occurred? Was the pace slow or rapid?"), own performance ("How successful were you in performing the task? How satisfied were you with your performance?"), effort ("How hard did you have to work (mentally and physically) to accomplish your level of performance?"), and frustration ("How irritated, stressed, and annoyed vs. content, relaxed, and complacent did you feel during the task?"). Each subscale is rated on a 21-point scale (all from 1 = *very low* to 21 = *very high* except the performance subscale which is rated from 1 = *perfect* to 21 = *failure*).

As another explorative variable, we measured task engagement using the Utrecht Work Engagement Scale (Sautier et al., 2015; Schaufeli et al., 2006). This scale assesses mental absorption, enthusiasm for the task, and persistence to continue with it. Eight items are rated on a 7-point scale (from 1 = *I do not agree at all* to 7 = *I fully agree*; $\alpha = .77$). We also exploratively measured fatigue with a single item asking the participants to indicate how tired they were currently feeling on a 7-point scale (from 1 = *not tired at all* to 7 = *extremely tired*).²

Design and Procedure

There were three experimental groups: Participants in the liked music group ($n = 41$) took the sustained attention task while listening to the same well-liked songs from Study 1. Participants in the disliked music group ($n = 36$) took the task while listening to a playlist of songs that were liked the least or disliked the most. In a pilot study, songs were selected from a list of least popular tracks among German students (e.g., *Schlager* music) and rated on a 7-point Likert scale (1 = *I do not like this song at all* to 7 = *I like this song very much*). The following songs, used in the disliked music group, received low average ratings: *Wenn du tanzt* by Schleini ($M = 2.13$), *Rappin for Jesus* by Pastor Jim Colerick ($M = 2.23$), *Liebe ohne Leiden* by Udo Jürgens ($M = 2.42$), *Nicht Verdient—The Nation Bootleg* by Michelle Matthias Reim ($M = 2.5$), *Kein Schwein ruft mich an* by Max Raabe ($M = 2.67$), and *Happy Hippie Presents* by Joan Jett ($M = 2.7$). While the disliked playlist included several German-language *Schlager* songs, these were selected based on pilot ratings identifying them as strongly disliked by our target population. Given that genre and language are central to musical valence, we treated them as inherent to the manipulation rather than as confounds. Nonetheless, we acknowledge that linguistic content may independently influence cognitive-affective responses and suggest this as a direction for future research. The playlists in both music groups had the same duration. The control group ($n = 40$) took the same task without any background music.

The procedure was the same as in Study 1, with no breaks or separate sets. Participants first answered the trait boredom questions. After this, the sustained attention task began. This was followed by ratings of state boredom, task characteristics, task load, task engagement, and finally the demographics questions.

Transparency and Openness

This study was reviewed and approved by the Ethics Committee of the Department of Human-Centered Computing and Cognitive Science, University of Duisburg-Essen. The participants provided their informed consent to participate in this study. This study's design and hypothesis were preregistered (see <https://aspredicted.org/ph4cj.pdf>). The data were collected in 2023 and 2024. The data sets generated and analyzed for these studies are available at <https://osf.io/9rdpu/>.

Results

The dependent variable was the total number of correct answers in the vigilance task. For analysis purposes, we again divided the entire 12-min block into three 4-min segments (T1, T2, and T3) and measured the commission errors and omission error rates across these three blocks.

Preliminary Analyses and Time Differences

An independent samples *t* test between the two music groups confirmed that music liking was significantly different between the groups, $t(75) = 9.29$, $p < .001$, $d = 2.12$, such that, participants in the liked music group liked the songs more, $M = 3.98$, $SD = 0.93$, compared to those in the disliked music group, $M = 2.00$, $SD = 0.92$. Bivariate correlations across all three groups indicated that the total number of correct answers was negatively correlated with state boredom, $r = -.19$, $p = .03$. The commission errors were negatively correlated with task engagement, $r = -.18$, $p = .04$. There was a significant correlation between commission errors and the frustration subscale of NASA-TLX, $r = .18$, $p = .04$. For other correlations, see Table 2.

To confirm that overall performance decreased over time, we conducted a mixed-factorial ANOVA with group (liked music, disliked music, control; between-subjects) and time (T1, T2, T3; within-subjects) as factors, analyzing omission error rates. The three time points represented performance during the first 4 min (T1), second 4 min (T2), and last 4 min (T3) of the task. There was no significant main effect of group, $F(2, 114) = 0.80$, $p = .45$, $\eta_p^2 = .014$. However, there was a significant main effect of time, $F(2, 228) = 65.09$, $p < .001$, $\eta_p^2 = .363$. Tukey's honestly significant difference post hoc test showed that omission error rates at T1, $M = 0.10$, $SE = 0.00$, were lower than the error rates at T2, $M = 0.17$, $SE = 0.01$, $p < .001$, and T3, $M = 0.20$, $SE = 0.01$, $p < .001$. Finally, error rates at T2 were significantly lower than those at T3, $p < .001$. The interaction term was not significant, $F(4, 228) = 0.39$, $p = .81$, $\eta_p^2 = .007$.

Correlation analyses showed that posttask boredom was positively related to omission error rates in both T2, $r = .20$, $p = .03$, and T3, $r = .18$, $p = .04$. Moreover, perceived task easiness was positively

² We also measured music listening habits, arousal, and state procrastination, which are not reported here.

Table 2
Bivariate Correlations in Study 2

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Total correct answers	—													
2. Commission errors	-.37***	—												
3. NASA-TLX (overall)	-.12	.15	—											
4. NASA-TLX: mental demand	.07	.06	.65***	—										
5. NASA-TLX: physical demand	-.15	.03	.46***	.26**	—									
6. NASA-TLX: temporal demand	-.12	.03	.68***	.24**	.30	—								
7. NASA-TLX: performance	-.03	.17	.41***	.09	.03	.05	—							
8. NASA-TLX: effort	-.10	.08	.74***	.47***	.27**	.45***	.09	—						
9. NASA-TLX: frustration	-.12	.18*	.64***	.22*	.05	.29***	.32***	.34***	—					
10. Fatigue	-.13	.05	.02	-.14	.07	-.00	.04	-.06	.21*	—				
11. Task engagement	.11	-.18*	-.09	.04	.19*	-.01	-.19*	.03	-.35***	-.29**	—			
12. Trait boredom	.04	-.02	.01	-.05	-.01	-.02	.10	-.08	.18*	.45***	-.32***	—		
13. Posttask boredom	-.19*	.11	-.08	-.22*	-.06	-.04	.14	-.12	.02	.16	-.42***	.18*	—	
14. Task boringness	-.12	.14	.02	-.13	-.06	.04	.15	-.06	.15	.02	-.45***	.14	.60***	—
15. Task easiness	-.11	.13	-.33***	-.31***	-.18†	-.13	-.16	-.29**	-.13	-.08	-.18†	.02	.40***	.36***

Note. NASA-TLX = NASA task load index.

† $p = .05$. * $p < .05$. ** $p < .01$. *** $p < .001$.

correlated with omission errors at T3, $r = .19$, $p = .03$. There were no correlations between error rates and overall task load or individual subscales.

Hypothesis Testing

We expected that participants listening to liked music during a vigilance task would outperform those listening to disliked music or no music at all. We conducted two separate one-way ANOVAs to test for group differences in sustained attention. In both analyses, the independent variable was group, a between-subjects factor with three levels: liked music, disliked music, and control. The first analysis examined total correct answers as the dependent variable. The second analysis used commission errors as the dependent variable. As shown in Figure 3, the results revealed no differences in correct answers, $F(2, 74.8) = 0.86$, $p = .42$, between the liked music group ($M = 148.90$, $SD = 17.75$), disliked music group ($M = 145.69$, $SD = 25.30$), and the control group ($M = 142.75$, $SD = 21.09$), or in the commission errors, $F(2, 72.5) = 1.00$, $p = .37$, between the liked group ($M = 4.76$, $SD = 4.02$), disliked music group ($M = 5.64$, $SD = 4.08$), and the control group ($M = 6.05$, $SD = 5.37$). These results indicate that background music valence (liked, disliked, or none) did not predict sustained attention performance. Additional Bayesian ANOVA analyses for the effect of group showed that, for the total correct answers, $BF_{10} = .162$, and for commission errors, $BF_{10} = .165$, indicating evidence in support of the null hypothesis.

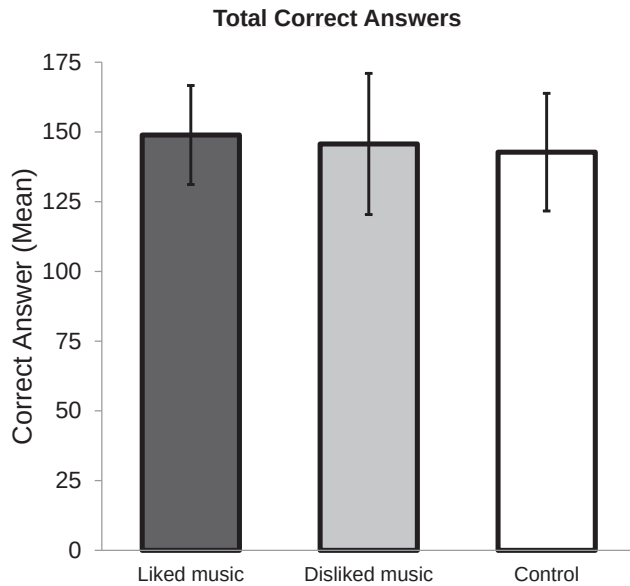
Exploratory Analyses

Task Load and Task Engagement. We conducted a one-way between-subjects ANOVA with group (liked music, disliked music, control) as the independent variable and overall task load as the dependent variable. We also conducted separate one-way ANOVAs to analyze group differences in task load subscales. There were no significant group differences in either the overall task load or any of the subscales. We also tested for group differences in task engagement. A one-way between-subjects ANOVA indicated a significant difference, $F(2, 74.4) = 8.58$, $p < .001$, $\eta^2 = .157$. A follow-up Tukey test revealed that the liked music group, $M = 4.20$, $SD = 0.92$, had a significantly higher engagement than the control group, $M = 3.34$, $SD = 0.94$, $p < .001$. Additionally, the disliked music group, $M = 3.81$, $SD = 0.59$, had stronger engagement than the control group, $p = .04$. There was no difference between the liked music group and disliked music group.

Task Characteristics, State Boredom, and Fatigue. We conducted separate one-way ANOVAs to examine group differences in perceived task easiness, task boringness, fatigue, and state boredom. There were no differences in task easiness, $F(2, 75.7) = 0.28$, $p = .75$, $\eta^2 = .004$, or fatigue, $F(2, 75.5) = 1.82$, $p = .16$, $\eta^2 = .032$. However, significant differences were found in both task boringness, $F(2, 75.6) = 4.51$, $p = .014$, $\eta^2 = .075$, and state boredom, $F(2, 75.8) = 5.63$, $p = .005$, $\eta^2 = .097$. Post hoc tests using the Tukey test indicated that participants in the liked music group found the task less boring, $M = 3.49$, $SD = 1.45$, than those in the control group, $M = 4.45$, $SD = 1.43$, $p = .009$. Additionally, the liked music group reported lower levels of state boredom, $M = 3.85$, $SD = 1.76$, than the control group, $M = 5.20$, $SD = 1.43$, $p = .002$. There were no other group differences.

Figure 3

Mean Number of Correct Responses in Study 2 (Music vs. Control Groups)



Note. Error bars represent standard errors.

Music Present Versus Absent. To examine the general effect of background music presence (regardless of valence), we collapsed the liked and disliked music groups into a single music-present group and compared it with the control (no music) group using independent-samples *t* tests. The groups differed in terms of task engagement, $t(115) = -4.05, p < .001, d = -0.79$, with the music groups reporting higher engagement, $M = 4.02, SD = 0.80$, than the control group, $M = 3.34, SD = 0.94$. They marginally differed on the performance subscale, $t(115) = 1.94, p = .05, d = 0.37$, such that, the control group perceived their performance more negatively, $M = 8.25, SD = 5.37$, compared to the music groups, $M = 6.47, SD = 4.33$. There were group differences in boredom measures. Specifically, the control group found the task more boring, $M = 4.45, SD = 1.43$, compared to the music groups, $M = 3.75, SD = 1.45$; $t(115) = 2.47, p = .015, d = 0.48$. The control group also reported stronger boredom after the task, $M = 5.20, SD = 1.92$, than the music groups, $M = 4.26, SD = 1.70$; $t(115) = 2.71, p = .008, d = 0.52$.

Discussion

In Study 2, we investigated the effects of liked and disliked music (vs. silence) on sustained attention performance along with self-reported task load, task engagement, fatigue, and boredom. There were no performance differences between the three groups. However, correlation analyses revealed that the number of correct answers was negatively correlated with posttask state boredom, and commission errors were negatively correlated with self-reported task engagement. Additionally, boredom was linked to higher omission error rates in the second half of the task. These findings suggest that greater boredom and lower engagement were associated with reduced detection accuracy. Interestingly, neither music presence nor music type significantly affected performance.

General Discussion

In this article, we investigated the influence of background music on sustained attention performance. We anticipated that music would enhance arousal and potentially impact task load. In Study 1, we investigated the impact of background music on sustained attention, exploring whether music-induced arousal mediated this effect and whether extraversion and boredom proneness moderated this relationship. Study 2 examined the effect of music on performance by comparing the effects of liked (positive valence) and disliked (negative valence) music on performance. Additionally, we explored how performance was related to perceived engagement with the task, fatigue, and task load.

Our findings supported the null hypothesis, showing that background music did not meaningfully affect sustained attention performance. While background music did elevate arousal, it did not enhance total correct detections, reduce commission errors, or decrease omission rates across the three 4-min intervals. These results challenge underload theories, which predict that increased arousal should prevent performance decline. Similarly, music type (liked vs. disliked) did not differentially influence performance. These findings align with previous work showing that music may raise arousal and reduce boredom without meaningfully improving vigilance performance (Burkhard et al., 2018; Kiss & Linnell, 2021).

Contrary to overload theory expectations, we found no evidence that background music impaired performance because of increased cognitive load or exhaustion (Alikonis et al., 2002; Becker et al., 1995; North & Hargreaves, 1999). Although music did not affect most NASA-TLX subscales, participants in the music condition, especially when listening to liked music, reported feeling more successful at completing task goals. This suggests a dissociation between subjective perceptions of performance and actual task outcomes. The influence of music on perceived interest and engagement may be valuable, particularly given that boredom and monotony are known stressors that impact performance (Wylie et al., 1985).

We measured momentary feelings of boredom immediately after task completion. Participants exposed to music reported lower post-task boredom and found the task less boring compared to those in the silent condition. We observed a negative correlation between boredom and correct detections, which intensified over time. However, performance did not differ significantly between music and control groups despite differing boredom levels. Omission error rates, though associated with boredom, were unrelated to task load or fatigue. These findings suggest that boredom increased over time and was linked to accuracy declines. Yet, the absence of performance differences across conditions challenges the predictive powers of both underload and overload theories.

In Study 1, we investigated whether extraversion and boredom proneness were associated with vigilance decrement and whether these traits moderated the relationship between arousal and performance. Introverts consistently outperformed extraverts on correct detections, particularly in the final minutes of the task, supporting previous findings (Beauducel et al., 2006; Koelega, 1992; Shaw et al., 2010). However, increasing arousal through music did not differentially affect performance across personality types. This contradicts predictions from arousal-based models of extraversion (Davies et al., 1969; Davies & Hockey, 1966). These results indicate that personality traits such as extraversion influence vigilance performance independently of arousal manipulation.

In Study 1, we also explored whether trait boredom moderates the impact of background music on performance. Trait boredom was not a significant moderator in the relationship between music and performance. Our use of a short 12-min task may explain the absence of expected effects of boredom-prone individuals, who might show performance declines in longer tasks because of sustained understimulation. Previous studies reporting such findings used 30-min tasks (Sawin & Scerbo, 1995). Moreover, our findings differ from Kass et al. (2001) who found effects in the first 10 min of task performance, indicating that other variables may moderate these effects.

Neither underload nor overload theories provide a comprehensive account of our findings. Underload models fail to explain the elevated boredom levels despite low task demands, while overload perspectives do not account for high task load ratings in simple tasks. Additionally, the literature lacks clarity on the concept and definition of boredom, with some theories treating arousal as a subcomponent (Alkonis et al., 2002; Hitchcock et al., 1999; Scerbo et al., 1992). This conceptual ambiguity complicates interpretations, particularly since boredom can arise from both low and high arousal states (Merrifield & Danckert, 2014; Thackray, 1981). Our results align with the notion that boredom and decreasing arousal are common in repetitive vigilance tasks, but they are not sole drivers of performance decrement.

An alternative interpretation is that initially easy tasks that are designed to require low self-control paradoxically become challenging over time as efforts to maintain attention increases (Bieleke et al., 2021; Wolff & Martarelli, 2020). In other words, tasks perceived as easy may require increasing effort over time to sustain attention, leading to cognitive fatigue. As boredom increases with time-on-task, participants may expend more self-control to maintain focus, which could deplete cognitive resources. This perspective suggests that boredom, both as a motivational signal and an emotional state, drives disengagement in vigilance tasks (Bench & Lench, 2013). While this aligns with both simple and complex tasks (Westgate et al., 2017; Westgate & Wilson, 2018), further clarity is needed on how task difficulty and boredom interact to affect sustained attention.

To better understand this dynamic, we turn to the meaning and attentional components model (MAC; Westgate & Wilson, 2018), which we propose as a novel and theoretically integrative framework in this context. This model conceptualizes boredom as arising from a mismatch between internal states and external demands, whether because of understimulation or overstimulation (also see Danckert & Elpidorou, 2023). The MAC model specifically posits that boredom results from a mismatch between task demands and available cognitive resources, distinguishing two key factors: attention and meaning. Understimulation occurs when a task is too simple, failing to engage attentional resources (e.g., repetitive tasks like writing “cd”), leading to boredom. Conversely, overstimulation happens when task demands exceed one’s cognitive capacity, such as during complex or fatiguing tasks. Boredom increases in both cases, with understimulation and overstimulation producing similar disengagement. This relationship is quadratic: Both overly simple and overly difficult tasks can induce boredom. Additionally, meaning plays a role: Boredom intensifies when tasks lack personal significance or perceived value. The model suggests that optimal boredom reduction occurs when both attentional engagement and task meaningfulness are maximized.

Interpreted through the MAC model, our findings suggest that while background music increased subjective engagement, it was insufficient to produce measurable improvements in vigilance

performance, likely because background music only partially addressed the two components of boredom (i.e., attention and meaning). The music served as an external stimulant that helped offset understimulation, as evidenced by higher engagement ratings in the music conditions. However, performance remained unaffected, which implies that the task still lacked personal relevance or perceived purpose, which is the second key component of the MAC model. This dissociation between engagement and performance supports the idea that stimulation alone is insufficient to sustain attention over time unless the task is also imbued with meaning. Participants may have experienced the task as more tolerable or less boring with music, but not meaningful enough to maintain the motivational drive required for sustained cognitive performance. This interpretation is consistent with the MAC’s prediction that optimal attentional functioning arises from a balance of stimulation and perceived meaning. In short, in light of the MAC model, we contend that vigilance tasks likely lack sufficient stimulation and meaning, contributing to boredom. Szalma et al. (2014) support this interpretation by showing that both visual stimulation and perceived meaning affect monotony in vigilance tasks. Thus, although music may have alleviated subjective boredom, it did not engage the motivational mechanisms necessary for performance enhancement.

Our study contributes a novel theoretical extension of the MAC model by applying it to the domain of auditory stimulation and sustained attention for the first time. Although the MAC model was not part of our initial framework, we introduce this model here post hoc as a theoretically powerful explanation and a conceptual bridge that reconciles inconsistencies observed across overload and underload perspectives. We believe it is a robust lens that accounts for our observed dissociation between subjective engagement and behavioral performance. To our knowledge, this is the first study to propose the MAC model in the context of music and sustained attention. By highlighting how attentional engagement and task meaning interact with stimulation, the MAC model provides more nuanced understanding of vigilance performance. We believe this model could help future research move beyond the dichotomy of resource versus arousal theories, offering a more integrative understanding of boredom-related performance effects in vigilance tasks.

Recent research by Luna et al. (2022) provides further support for this integrative view. Investigating performance across single, dual, and triple vigilance task conditions, they found that dual-task performance remained stable, whereas performance declined in both the single- and triple-task conditions. This pattern challenges the traditional resource depletion account, which would predict greater decline in the triple-task condition only. Interpreted through the MAC lens, these findings underscore the critical role of optimal engagement rather than task load alone in sustaining attention. Notably, participants reported greater fatigue in the single task condition, supporting the idea that understimulation may paradoxically tax the cognitive resources because of boredom-induced fatigue (Milyavskaya et al., 2019).

Our results suggest that while background music can reduce boredom and enhance subjective engagement in brief and monotonous tasks, it has only negligible effects on sustained attention performance. Given that boredom is recognized as a critical factor influencing task completion and performance (Wylie et al., 1985), future research should move beyond traditional overload/underload dichotomies. Instead, adopting emerging boredom-based models like MAC can offer richer insights into how attentional demands,

perceived task meaning, affective responses, and individual traits jointly influence vigilance outcome.

Importantly, we believe that this perspective opens up new avenues for intervention designs. For example, rather than merely adding external stimulation (e.g., music), future studies could manipulate task framing, personal relevance, and allow for individualized music selections to enhance both stimulation and meaning. Such approaches could yield more consistent improvements in performance, especially in real-world vigilance contexts, such as air traffic control or surveillance where attentional lapses carry high stakes. Ultimately, the MAC model offers a promising framework for rethinking our understanding of engagement in sustained attention tasks and highlights the importance of aligning both cognitive and motivational dimensions for optimal performance.

Limitations and Future Research

This article tested assumptions rooted in two main perspectives: the overload and the underload perspectives. While each perspective offers compelling arguments on vigilance deterioration, they do not fully integrate the underlying resource and arousal theories (Finomore et al., 2009). In challenging the literature, we did not find an answer that aligned with either of these perspectives. This theoretical ambiguity highlights the need for more comprehensive models that move beyond static notions of resource depletion and understimulation. Future research could explore alternative models to better understand the underlying factors influencing vigilance decline. It is possible that neither underload nor resource depletion may solely account for vigilance decrement, but short-term changes in attentional capacity should also be considered (Finomore et al., 2009). For instance, the malleable attentional resources model (Young & Stanton, 2002) proposes that depending on task circumstances, the size of the resource pool may adjust to match reduced demand, potentially resulting in null effects of resource depletion in tasks of lower demand.

However, while the malleable resources framework might account for flexibility in attentional allocation, it does not fully explain why participants may disengage from tasks they are cognitively capable of completing. To address this gap, future work should incorporate motivational and affective dimensions of sustained attention. The MAC model (Westgate & Wilson, 2018) offers a promising framework in this regard. It posits that boredom arises when tasks are mismatched to the individual's attentional capacity or lack perceived meaning, which are factors that may better account for the dissociation we observed between subjective engagement and performance. Future studies should manipulate both the attentional meaningfulness dimensions of vigilance tasks to test whether music, or other forms of stimulation, can reduce boredom and improve performance when both components are optimized.

Other limitations concern the task itself. First, Davies et al. (1973) found that music improved vigilance performance in a difficult version of the task, even if the music was not liked. In our study, we found that, although liked music successfully increased task engagement compared to disliked music, it did not influence performance. Accordingly, it is possible that the vigilance task we used was not difficult enough to reveal performance differences induced by background music. Future studies should replicate these findings under varying levels of task difficulty. Our task was relatively simple and may not have provided sufficient cognitive challenge to allow

for music to meaningfully influence performance. This suggests that the impact of music on sustained attention might be more noticeable in tasks with higher cognitive demands or greater task difficulty. Future studies should use tasks that vary in difficulty. This would help identify conditions where music meaningfully affects performance. Moreover, manipulating difficulty alone may be insufficient if the task still lacks perceived meaning. Therefore future work should explore how the combination of difficulty and meaningfulness affects vigilance outcomes.

Another challenge is related to task duration. A standard vigilance task can last up to 9 hr (Doan et al., 2006), posing practical limitations for laboratory settings. Consequently, shorter versions of the tasks (10- and 5-min durations) have been implemented successfully (Loh et al., 2004). Although we employed a 12-min version that has previously demonstrated performance decrements (Temple et al., 1997), we did not find significant results. Previous research suggests that performance decrements become more apparent in tasks lasting 20–30 min (Mackworth, 1948), with others recommending durations of at least 30 min for more robust vigilance measurements (Al-Shargie et al., 2019). Our findings suggest that shorter task duration may have limited the potential for boredom and performance decline to emerge in the way that longer tasks might. Therefore, future research should consider using longer vigilance task durations to more effectively capture performance decrements and determine if longer exposure increases the likelihood of music influencing performance. Extending task duration may also allow for a more nuanced investigation of the temporal dynamics of boredom, engagement, and resource depletion, especially when tracked continuously over time.

One limitation of the present study is that we did not systematically compare different music genres or styles. In Study 1, we used popular and familiar songs that were generally well-liked, while in Study 2, we contrasted these with disliked, negative-valence songs. However, both sets of music were limited to specific genres, such as mainstream pop or regional favorites, and did not span a broad range of musical styles. This limits the generalizability of our findings, particularly given evidence that different music genres may differentially affect sustained attention. For example, Baldwin and Lewis (2017) found that slow-tempo pop music with positive valence reduced omission errors during the SART compared to negative-valence music or silence, while Corhan and Gounard (1976) reported more correct detections with rock music compared to easy-listening music. Similarly, Kirk et al. (2022) found that instrumental genres such as piano, jazz, and lo-fi music improved performance relative to silence. These findings suggest that genre-specific characteristics—such as tempo, instrumentation, or lyrical content—may interact with task demands to influence attentional outcomes. While our findings showed no meaningful difference between liked and disliked music, subsequent studies may benefit from testing whether genre, task difficulty, and task meaningfulness interact to shape vigilance performance, and whether individual music preferences or levels of task engagement moderate these effects.

Finally, we expected that boredom-prone individuals would benefit from music stimulation in terms of performance; however, our results did not support this. One possible reason could be related to our music selection process. Although considerable thought went into the pilot studies and the selection of liked and disliked songs, we might not have fully considered other aspects of liked music and the contextual influence of music on task performance.

By opting for predefined music choices to ensure consistency across participants, we may have overlooked the potential benefits of individually preferred music. Kiss and Linnell (2021) allowed participants to choose their own music, which reduced mind-wandering in a low-demand task. Therefore, it is plausible that generally liked music (e.g., charts music) and self-chosen music differ in their effectiveness. Future studies should investigate how self-selected music may enhance both stimulation and task meaningfulness, which are core mechanisms in the MAC model, and test whether this interaction predicts better attentional outcomes than externally imposed music.

Conclusion

In this study, we examined the impact of music on vigilance performance, considering the expectations of both underload and overload perspectives. We systematically analyzed the roles of arousal and relevant personality traits in this context. While our results provided partial support for both perspectives, neither offered a comprehensive explanation of the observed effects. Our findings suggest that the traditional vigilance literature could benefit from integrating insights from boredom research. Future research should consider not only the stimulatory aspects of vigilance tasks (e.g., boredom, arousal, attentional engagement) but also the motivational dimensions (e.g., task meaningfulness, incentives, and interest). This more comprehensive approach could lead to a more nuanced understanding of vigilance and sustained attention.

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