Psychology, 2023, 14, 90-101
https://www.scirp.org/journal/psych
ISSN Online: 2152-7199
ISSN Print: 2152-7180

The Effect of Distraction on Cognitive Performance as a Function of Anxiety

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How to cite this paper: Paranjpe, A., Furnham, A., & McClelland, A. (2023). The Effect of Distraction on Cognitive Performance as a Function of Anxiety. *Psychology, 14,* 90-101.
https://doi.org/10.4236/psych.2023.141006

Received: November 30, 2022
Accepted: January 28, 2023
Published: January 31, 2023

Abstract

Previous research has demonstrated the effect of distraction on cognitive performance as a function of trait anxiety. In the presence of pop-music, background office noise and silence, participants with varying levels of trait anxiety carried out an established cognitive performance (IQ) test. It was predicted that there would be a main effect of background sound: all participants would perform more poorly in the presence of music and noise than in silence. Results confirmed this prediction, with performance being highest in silence followed by music and noise respectively. It was also predicted that anxious individuals would do less well on the test in music and noise conditions than less anxious individuals, but performance would be similar in silence. Results partly supported this hypothesis. Performance of both groups was similar in silence, but the high-anxiety group performed *better* on the test than the low-anxiety group. Implications and limitations are discussed.

Keywords

Distraction, Noise, Music, Cognitive Performance, Anxiety

1. Introduction

Researchers have investigated the effects of music on job performance for over 70 years but their findings have been inconsistent (Landay & Harms, 2019; Perham & Vizard, 2011; Roberts, 1959). This experimental study focuses on the role of trait anxiety on cognitive performance in the presence of noise, music and silence. Most of the research on individual difference correlates of distraction has focused on arousal concepts like extraversion-introversion rather than on neuroticism and anxiety which is the focus of this paper.

Research shows that the effects of distraction (music) on job performance depend on the nature of the task being performed, the nature of the distraction (music, noise, alarms) and the personality of the individuals (Furnham, 2021). For example, Kiger (1989) made high school students read a passage of literature in one of three conditions; silence, low information-load music or high information-load music. The music was chosen based on loudness, complexity, variety and tonal range. The results showed that comprehension scores were significantly higher when students were listening to the low information-load music as opposed to silence or the high information-load music. These findings suggest that certain types of music (slow, soft and repetitive) have the potential to enhance performance by providing an optimal level of arousal.

There are a number of different accounts of the effects of distraction, including the semantic auditory distraction of performance. For instance, working from a cognitive psychology perspective, Jones and colleagues (Jones & Macken 1993; Jones et al., 2010; Marsh et al., 2008) developed an interference-by-process account where implicit processing of order information from changing state sounds conflicts with the subvocal rehearsal as a means to retain and retrieve (i.e., memorise) information. Thus, tasks that involve semantic processing like reading comprehension are impaired more by sounds with semantic information (i.e., lyrical music) than those without it. Hence the type of distraction has a differential effect on the type of task performed.

Other studies have examined the moderating role of individual differences, particularly extraversion, in how people are affected by the presence of music during cognitive tasks (e.g., (Avila et al., 2011; Furnham & Allass, 1999; Furnham & Bradley, 1997; Shepherd et al., 2015; Lim et al., 2022)). For example, although Furnham and Allass did not find an overall effect of background music, they did find that extraverts' performance was enhanced by the presence of complex music while that of the introverts was made worse. This type of finding can be explained by an appeal to Eysenck's (1967, 1994) theory of personality, where he states that introverts and extraverts have differing levels of cortical arousal.

Other studies have looked at the corresponding effect of noise and found that it can also influence cognitive performance (e.g., (Gheewalla et al., 2021)). Ylias and Heaven (2003) conducted a study with undergraduate students and found that television noise had a detrimental effect on performance in a reading comprehension task. Banbury and Berry (1998) found a similar detrimental effect of taped office noise on undergraduate students' performance on both mathematical and recall tasks.

This led several researchers to investigate the differential effects of music and noise on cognitive performance. Cassidy and MacDonald (2007) found an overall detrimental effect of background sound (music and noise). Scores were lowest in the presence of high-arousal music, followed by low-arousal music, noise and silence respectively. The researchers explained the findings in terms of cognitive effort. Listening to high arousal music, that is cognitively demanding, will require more effort and leave less attention capacity for simultaneous tasks. Low arousal music will be less cognitively demanding than high arousal music, but still more demanding than noise (Hargreaves & North, 1999). Hence, their results suggested that music is more distracting than noise. This is particularly true if it is familiar, fast, loud and vocal music.

In contrast, Furnham and Strbac (2010) found that noise is more distracting than music. They found a main effect of background sound and an interaction between personality and background sound. The results also showed that performance in the presence of music was slightly better than that in noise, but the difference was not significant. Dobbs et al. (2011) required school children to take a personality questionnaire as well as three test of general cognitive ability in silence, in the presence of UK garage music or in background noise. The researchers found a main effect of background sound, such that all participants performed more poorly in the presence of music and noise than in silence. They also found that introverts performed more poorly in music and noise, compared to extraverts. Moreover, they also found that on two of the three tests, performance in music was better than that in noise.

While the findings of the differential effects of music and noise on performance have been variable, the effects of personality traits such as introversion/extraversion have been far more consistent. Further, Reynolds et al. (2014) investigated the association of another personality trait (neuroticism) and cognitive performance under distraction. They predicted a main effect of background sound and a negative effect of neuroticism on task performance in the presence of background sound. The results confirmed the hypotheses, showing that the stable participants performed better on the mental arithmetic task in the presence of background sound than the unstable participants.

Many studies have looked at the cognitive consequence of trait neuroticism as well as a more specific facet namely trait anxiety which are positively correlated. Eysenck (1967, 1994) and Hayes et al. (2008) in extensive work on anxiety and cognition, proposed that neuroticism is mediated by arousal in the limbic system, and individuals high on neuroticism are more likely to be affected by stressors because it makes them exceed their optimum level of arousal. Recent studies have provided some support for this idea and have shown the impact of anxiety-inducing distraction on cognitive performance (e.g., (Denkova et al., 2010)). Hence, the background sound (music and noise) may have served as a stressor, causing neurotic individuals to exceed their optimal arousal leading to a detriment in performance, in comparison to less neurotic individuals.

Research has suggested that anxiety is associated with attentional bias, especially towards threat material, and impairment on relatively demanding tasks (Eysenck, 1985). There is much less work on the role of anxiety and neuroticism on such tasks as intelligence test taking. However, in one salient study Moutafi et al. (2006) showed that trait Neurotics were more likely to be affected by test anxiety and by induced anxiety, and that a high-anxiety group scored lower on the intelligence test than the low-anxiety group. Furthermore, when test anxiety was partialled out, Neuroticism did not significantly correlate with intelligence.

2. This Study

This study aimed to examine the effect of distraction on cognitive performance as a function of anxiety. Participants were required to complete a cognitively demanding test (i.e., a standard 50 item IQ test) in the presence of music, background noise or silence. Their anxiety levels were measured through an anxiety inventory to distinguish between high and low anxiety individuals' performance on the test. We also included a measure of trait neuroticism.

Previous research has established the negative effect of anxiety on test performance (McDonald, 2001; Moutafi et al., 2006) and the prediction was that this effect would be accentuated in the presence of background sound (music and noise). This study also measures both trait and state anxiety, as it was believed that state anxiety might have a more direct effect on performance in this case. In addition, it was predicted that music would be more distracting than noise as contemporary vocal (rather than instrumental) music was used in this study, and this would therefore impose a greater cognitive load (Iwanaga & Ito, 2002). It was also likely to be familiar to the participants, and therefore more distracting than neutral background office noise.

Hypotheses

1) There will be a main effect of background sound: Performance by all individuals will be worse in the presence of music and noise than in silence.

2) Music will be more distracting than noise: Individuals will perform more poorly in the presence of music than noise.

3) There will be a main effect of anxiety: Individuals high on anxiety will perform more poorly than those low on anxiety, in all conditions.

4) There will be an anxiety x condition interaction, such that individuals high on anxiety would perform more poorly in the presence of music and noise than those low on anxiety.

3. Method

3.1. Participants

There were 57 participants; they were all undergraduates at an elite UK university. The mean age of the participants was 19.68 years (*SD* = 1.97 years) and they were predominantly female (73.68%). All were native English speakers. An a priori power analysis was conducted using G*Power 3.1 (Faul et al., 2007) indicated that to detect a standardised effect size of $f = .25$ (moderate), with a 5% significance level and 95% power, the minimum sample size required was 43 individuals.

3.2. Materials

Two questionnaires and a selection test were given to each of the participants.

1) *The Big Five Inventory-2 Short Form* (BFI-2-S) (John & Soto, 2017), is an abbreviated version of the 60-item questionnaire that assesses the Big Five personality domains. It has 30 questions and retains much of the reliability and validity of the full measure. In this study we only used two scales: Extraversion and Neuroticism.

2) *State-Trait Anxiety Inventory* (STAI) (Spielberger, 1983), is a measure of anxiety in adults. It differentiates between temporary state-anxiety and the more long lasting trait-anxiety. It evaluates these states based on feelings of apprehension, worry, and nervousness. It has 40 questions in total, with 20 assessing each measure.

3) Wonderlic Personnel Test (WPT) (Wonderlic, 1992) is a measure of general cognitive ability. It consists of 50 items of increasing difficulty. It tests individuals on algebraic, geometric and language skills.

Sounds

Participants were provided with noise cancelling headphones through which the background sound was played.

1) Music. A 15 minute playlist with songs selected from the UK top 100 charts was created on GarageBand music mixing software (https://www.apple.com/uk/mac/garageband/). Songs likely to be familiar to the participants' demographic were selected. They were *This Is Real* by Jax Jones and Ella Henderson, *Don't Start Now* by Dua Lipa, *I Don't Care* by Ed Sheeran and Justin Bieber, *Bad Girls* by Lil Skies, *Bad Guy* by Billie Eilish and *Circles* by Post Malone.

2) The background noise was obtained from YouTube (SoundLikeTube, 2013) and contained sounds from a simulated office environment, such as those from printers, keyboards, colleagues talking and pen on paper (SoundLikeTube, 2013). The clip was two hours long, but only the first 15 minutes were used in the study.

3.3. Procedure

Participants were asked to read and sign a consent form before starting the experiment, and received course credit for their participation in the study. They were seated individually in an experimental cubicle. They were not timed while completing the questionnaires, but all participants took less than 10 minutes to complete each one. The order of presentation of the two questionnaires was counterbalanced. Participants were asked to put on the headphones and told that they may or may not hear some sounds through them. Depending on the condition, they received music, background office noise, or no sound. The volume on the headphone was preset to 70 decibels, which is a comfortable and safe noise level (The National Institute of Occupational Safety and Health, 2018). They were then given the Wonderlic Personnel Test and asked to answer as many questions as they could in 15 minutes. The music/background noise on the headphones began at the same time as the test. After 15 minutes, participants were told to stop the test and their answer sheets were collected. Each participant was debriefed and thanked for their participation. Each experimental session ran for approximately 40 minutes. Departmental ethical permission was sought and granted.

4. Results

The participants in this study had relatively low levels of anxiety, with an average state anxiety score of 45.77 (SD = 6.38) and an average trait anxiety score of 46.88 (SD = 5.71). The mean Extraversion score was 18.47 (SD = 4.82) and mean neuroticism score was 17.72 (SD = 5.34). Scores on the WPT indicated that these participants were well above average—with their scores approximately 1.5 standard deviations above the norm (Wonderlic, 1992).

Table 1 presents the correlations among measures taken in this study. As expected, state and trait anxiety were significantly correlated. State anxiety also significantly correlated with Extraversion but trait anxiety did not. However, trait anxiety was significantly correlated with Neuroticism. There was also a significant negative correlation between extraversion and neuroticism. Lastly, there was a positive, but non-significant, correlation between state anxiety and WPT scores.

Before conducting further analyses, a median split on the state anxiety scores was used to create high and low anxiety groups. A 3 × 2 ANCOVA was then conducted with background sound (silence, music or noise) and anxiety (high or low) as independent variables and performance on the WPT test as the dependent variable. Measures of trait anxiety, extraversion and neuroticism were treated as covariates.

There was a significant main effect of background sound on performance on the WPT, $F(2, 48) = 7.92$, $p = .001$, $\eta_p^2 = .25$. Bonferroni-corrected pairwise comparisons revealed that performance in silence ($M_{Adj} = 35.41$) was significantly higher than that in music ($M_{Adj} = 30.34$) and in noise ($M_{Adj} = 29.32$), but performance was not significantly different between music and noise. There was also a significant main effect of anxiety on test performance $F(1, 48) = 7.17$, $p = .010$, $\eta_p^2 = .13$, with performance of the high anxiety group ($M_{Adj} = 34.04$) being higher than that of the low anxiety group ($M_{Adj} = 29.34$).

Table 1. Correlations among all variables analyzed in this study.

	State Anxiety	Trait Anxiety	Extraversion	Neuroticism	WPT
State Anxiety	-				
Trait Anxiety	0.568**	-			
Extraversion	0.414**	0.169	-		
Neuroticism	−0.198	0.355*	−0.351**	-	
WPT	0.211	−0.032	0.093	−0.126	-

*$p < 0.05$, **$p < 0.001$.

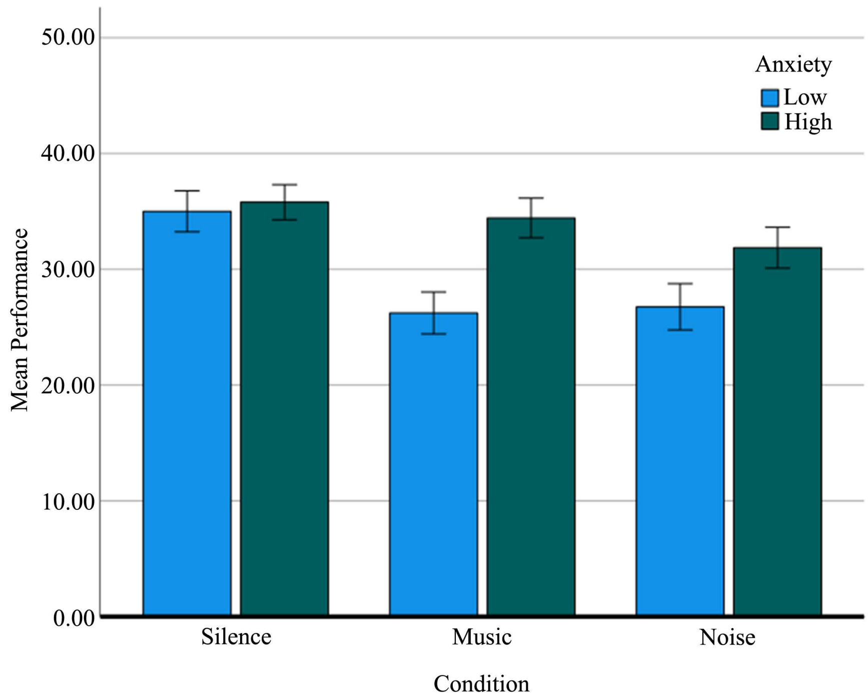

Figure 1. WPT performance as a function of state anxiety for each sound condition, controlling for trait anxiety, extraversion and neuroticism. *Note.* Error bars are ±1 SE.

However, there was no significant interaction between anxiety and condition on test performance, $F(2, 57) = 2.37$, $p = .105$, $\eta_p^2 = .09$. As can be seen in **Figure 1**, mean performance in silence in the low anxiety group and high anxiety group is similar. In the presence of both music and noise, the high anxiety group performed better than the low anxiety group.

5. Discussion

The mean performance in the presence of both music and noise was lower than that in silence. This supports the first hypothesis, and is in accordance with previous literature in the field (Furnham & Bradley, 1997; Furnham & Allass, 1999; Cassidy & MacDonald, 2007; Furnham & Strbac, 2010; Dobbs, Furnham, & McClelland, 2011). It perhaps comes as no surprise that information processing is more efficient without distractions be it music or noise.

The second hypothesis, that music would be more distracting than noise, was not supported. Other studies comparing the differential effects of music and noise have also produced conflicting findings (Cassidy & MacDonald, 2007; Furnham & Strbac 2010; Dobbs et al., 2011). Hence, it is possible that the difference in the degree of distraction caused by music and noise may critically depend on the nature of the task being performed, and music/noise heard.

The third hypothesis was that there would be a main effect of anxiety. The results showed that there was no correlation between test performance and trait anxiety and a *positive* correlation with state anxiety, in direct contrast to the hypothesis. This positive correlation between anxiety and test performance, meant that individuals with higher in state anxiety scored higher on the test. This conclusion was reinforced by the ANCOVA results, which established that there was an effect of anxiety on test performance, however not in the direction predicted. Performance in the high anxiety group was found to be higher than that in the low anxiety group.

The fourth hypothesis was that there would be an anxiety x condition interaction, such that individuals high on anxiety would perform more poorly in the presence of background sound (music and noise) than individuals low on anxiety, but this effect would be absent in silence. The hypothesis was partly supported. Mean performance in silence was similar in the two groups. However, there was a tendency for performance in the *high anxiety* group to be better than the *low anxiety* group in the presence of both music and noise, thus in the opposite direction to that predicted, but the result did not reach statistical significance.

This was an unusual finding, as most previous studies have found that anxiety hinders performance on tests (McDonald, 2001). A possible reason for this could be that anxiety levels were relatively low in this study and thus a small amount of anxiety may have actually helped the participants. As seen in Yerkes-Dodson law (Teigen, 1994; Dobson, 1982) there is a curvilinear relationship between arousal and performance, with the optimum point being at moderate levels of arousal. In other words, arousal increases performance up to a point, and beyond that, performance gets worse. For instance, Deshpande and Kawane (1982) found that a moderately anxious group would perform better in a serial recall task than a low or high anxious group. Also, in a study conducted with older adults, Potvin et al. (2013) also found that a moderate level of state anxiety could have beneficial effects on performance in tests of verbal fluency and general cognitive functioning.

In earlier work Eysenck (1985) noted that moderate scores on anxiety/neuroticism were associated with exam success because the anxiety associated with failure prompted individuals to work harder. However, high anxiety/neuroticism scores are associated with lower levels of success, because of the effects on test performance.

It is perhaps understandable that participants in this study had relatively low levels of state anxiety because they were aware that their performance on the test had no serious consequences. They also had relatively low levels of trait anxiety and this may be because individuals high in trait anxiety are unlikely to have volunteered for such a study. Moreover, individuals high in trait anxiety would have also been high in state anxiety when they were confronted with a timed cognitive test. It, therefore, appears that those higher in state anxiety (but still relatively low over all) performed better in the test. It is important to note that the optimum level of anxiety that would enhance performance would very significantly across individuals based on their personality and contextual factors.

One ergonomic implication of this study is to investigate the state anxiety (i.e., neuroticism) scores of those doing important cognitive tasks, perhaps associated with safety equipment, in the presence of uncontrollable noise, or indeed self-selected and played music. Clearly, performance on these tasks reduces and therefore it may be advisable to ban the use of personal distractions and where possible reduce sound, possibly by the use of headphones.

In summary, the results of this study suggest that cognitive performance is adversely affected by auditory distractions and this effect can be mitigated to some extent by moderate levels of state anxiety. This has important implications for both organizations and individuals. For organizations, it suggests the need to create "quiet" zones to limit auditory distractions. In addition, carefully created measurable, and time-bound goals can raise state anxiety to optimal levels. For individuals, an understanding of their traits and their response to stressors can help them identify appropriate roles and workplaces. Some tasks like air traffic control are complex and involving and as a consequence stable people are selected and work in a very controlled quiet and cool environment.

This study, like all others had limitations. It needs to be replicated it with a larger sample size, using a wider variety of cognitive tasks, and exploring in more detail noise sensitivity and its relationship with anxiety type. Our sample had students with higher IQ and lower anxiety compared to population norms though the scores were normally distributed. Moreover we had a predominance of female participants and it would have been desirable to have had a more balanced group in terms of gender. However there is essentially no reason to believe that we could not replicate the findings.

Data Availability

This is obtainable from the first author upon request.

Ethics

This was sought and obtained (CEHP/514/2017).

Informed Consent

Participants gave consent for their anonymised data to be analysed and published.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Author Contribution

A. Paranjpe: Data collection, initial analysis and write up; A. Furnham: Visualisation, writing-review and editing; A. McClelland: Concept, supervision and editing.

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