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Investigating the effects of background noise and music on cognitive test performance in introverts and extraverts: A cross-cultural study

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Abstract

Previous research found that introverts performed worse than extraverts on cognitive tasks in the presence of noise or music in a Western sample but not in an Asian sample. This is a cross-cultural part replication of these studies using a Western (British) (N = 45) and Asian (Singaporean) (N = 45) sample. Participants engaged in three cognitive tests in the presence of pop songs, background noise, and in silence. It was predicted that for British participants, introverts would perform worse than extraverts on all three tasks in the presence of background sounds, and performance would be worse in the presence of background sounds than in silence, but not for the Singaporean participants. The results did not show any performance differences between the background sound conditions for any of the tests across the two samples, nor any performance differences between extraverts and introverts across the background sound conditions, with three exceptions: extraversion for the British was a significant predictor of performance on the Raven's test in the silence condition; extraversion was a significant predictor of performance for both groups on the mental arithmetic task in the silence condition, and; extraversion was a significant predictor of performance for Singaporeans on the mental arithmetic task in the music condition.

Investigating the effects of background noise and music on cognitive test performance in introverts and extraverts: A cross-cultural study

Music has become increasingly prevalent and accessible in individuals' daily lives, with the advent of new online streaming services and portable music devices. Many individuals also work in noisy environments, given the rise in popularity of open-plan offices over more traditional closed-plan offices (Landay & Harms, 2019). As such, there has been an increase in the amount of research examining the effects of these background sounds on cognitive performance, which is particularly important given the implications for learning and productivity in both educational and organisational work settings (Gheewalla et al., 2020; Jamshidzad et al., 2018; Lesiuk, 2005; Schwartz et al., 2017). The literature has focused on what sort of distraction (i.e., type of music) has an effect on what sort of (work) activity (e.g., reading, memorizing) (Gheewalla et al., 2020; Jamshidzad et al., 2018; Kang & Williamson, 2014; Salamé & Baddeley, 1989; Thompson et al., 2011) for what sort of individuals (e.g., introverts, neurotics) (Dobbs et al., 2011; Furnham & Bradley, 1997; Furnham & Strbac, 2002; Reynolds et al., 2014), and from which cultures (East, West) (Kou et al., 2018). In this study, we focus particularly on individual differences and culture, the latter factor of which has been relatively neglected.

Background sounds and cognitive performance

Previous studies have produced mixed evidence regarding the effects of background sounds on cognitive performance. Background noise has generally been found to negatively affect cognitive performance in both educational and work settings (Jahncke et al., 2011; Klatte et al., 2013), although specific types of noise, such as white noise, have not been found to negatively affect cognitive performance (Salamé & Baddeley, 1989). Background music, however, has been shown to have either a positive effect (Rauscher et al., 1993; Savan, 1999; Schellenberg & Hallam,

2006), negative effect (Cassidy & MacDonald, 2007; Dobbs et al., 2011; Furnham & Bradley, 1997; Furnham & Strbac, 2002), or no effect at all (Kou et al. 2018; Lehmann & Seufert, 2017; Reynolds et al., 2014) on cognitive performance.

These mixed findings can largely be explained through three factors: (1) the characteristics of the noise/music, (2) task characteristics, and (3) individual differences. In this study, we focus on the latter, and in particular, personality and cultural differences.

Several studies have found that certain types of music improved cognitive performance. Rauscher et al. (1993) found that listening to Mozart's music resulted in better performance in a spatial reasoning task; however, few have been able to replicate that finding. Kiger (1989) found that cognitive performance in a reading comprehension test was worse with complex "high-information load" music as compared to less complex "low-information load" music. Furnham et al. (1999) found that performance on a logic task was worse with more complex vocal music than with less complex instrumental music, although Furnham and Allass (1999) did not find any significant effect of music complexity on task performance.

Background sounds also have been found to have differing effects on different types of cognitive tasks. Dobbs et al. (2011) found that both background noise and music resulted in worse performance on both verbal and abstract reasoning tests. Crawford and Strapp (1994) found that vocal music had a significant negative effect on a linguistic logic test, but not on a visual maze-tracing test. This effect was also noted by Furnham (2001), and can potentially be explained in terms of the differing demands being placed on working memory resources when listening to vocal music and undertaking a linguistic task. Based on Baddeley's model of working memory (Baddeley, 1986), vocal features present in auditory stimuli will need to be processed first in the phonological loop and central executive, and as such, these areas will have less resources available

to process the linguistic information in the tasks, resulting in a detriment in task performance. The characteristics of both the background sounds and task have also been found to interact. When examining both music and task complexity, Gonzalez and Aiello (2019) found that complex music impaired performance on a complex word pair association task, but less complex music helped facilitate performance on a simple word search task.

Influence of individual differences

Individual differences, particularly personality traits, have also been examined as a potential factor in explaining the effects of background sounds on cognitive performance. Much of the work examining this has focused on the arousal-mood hypothesis (Thompson et al., 2001). This hypothesis postulates that music has the ability to increase arousal level and induce a positive mood in listeners, which can then facilitate cognitive abilities and performance (Landay & Harms, 2019). It is well documented that music can influence arousal and mood levels in listeners by altering autonomic and neurochemical arousal indices (see review by Rickard et al., 2005), and electrocortical activity in the brain (Schmidt & Trainor, 2001). This has been found to explain the effects of background sounds on cognitive performance across various cognitive tasks and auditory stimuli (music and noise). For example, Hallam et al. (2002) found that exposure to music that led to an increased level of arousal resulted in worse performance on a memory task in primary school children, as compared to calming music, which prompted a lower arousal level. Husain et al. (2002) also found that a change in arousal level as a result of listening to music was able to explain the variance in performance on a spatial task. They found that the higher the tempo of the music stimulus, a higher arousal level would be elicited, which resulted in a better performance in the spatial task.

Arousal level, in particular, has been linked to the extraversion-introversion dimension of personality, and Eysenck's (1967) theory of cortical arousal. This theory postulates that extraverts tend to seek arousal-inducing behaviours to increase their arousal level, as they are under-stimulated, whereas introverts are over-stimulated, and tend to avoid situations or behaviours that may induce an increase in arousal level. Evidence for this theory of arousal has been provided by Campbell and Hawley (1982), who found that, when studying or working, extraverts were more likely to seek out locations that provide greater levels of external stimulation, while introverts were more likely to avoid these locations, instead seeking out quieter areas with less external stimulation.

Numerous researchers have demonstrated a difference in performance between extraverts and introverts when they are exposed to background sounds. Cassidy and MacDonald (2007) had participants complete four different types of recall task, as well as a Stroop task, in the presence of background music designed to elicit a high arousal level, background music eliciting a low arousal level, background noise, and silence. They found that cognitive performance was worse with background music and noise as compared to silence, and introverts were more negatively impacted by highly arousing music than extraverts. In addition, extraverts reported working in more highly stimulating environments than introverts. Dobbs et al. (2011) examined cognitive performance on three different types of cognitive tests, and found that performance was worse with background noise and music than in silence. They also found that introverts performed worse in all tasks in the presence of background noise, and worse in two out of the three tasks with background music compared to extraverts. Furthermore, Mistry (2015) found that extraverts performed better in reading comprehension and problem solving tests in the presence of background music than in silence, whereas for introverts, they performed better in silence than with background music.

Work has continued in this area and most, but not all, studies have confirmed their hypotheses. For instance, in a recent study comparing 15 introverts and 15 extraverts, Deng and Wu (2020) found that in the presence of music, extraverts performed better than introverts on a visual pursuit task. However, no difference in performance was found when the task was carried out in silence.

Cultural differences

It is well established that cognitive styles differ across cultures. Asians favour a more holistic processing style, preferring to process and group objects based on their relational and contextual information, while Westerners favour a more analytic processing style, preferring to process and group objects based on their individual components and shared features (Chiu, 1972; Ji et al., 2004; Norenzayan et al., 2002). Members of Western societies have also been found to differ from non-Western societies in a variety of domains, such as spatial reasoning and induction styles (Henrich et al., 2010). As far as we know, no previous studies have looked at cultural differences and music distraction.

Within the body of research investigating the effects of background sounds on cognitive performance, several scholars have examined these in non-Western cultures and across cultures. Iwanaga and Ito (2002) examined memory performance in Japanese undergraduate students through a verbal memory task and a spatial memory task under four different sound conditions: vocal music, instrumental music, background noise, and silence. They found that verbal memory performance was most affected when listening to both vocal and instrumental music, but this was not seen in the spatial memory task. Schellenberg et al. (2007) looked at Canadian and Japanese participants, and found that background music can enhance performance on a variety of cognitive tests across cultures, and arousal level was a mediator in this relationship.

However, few studies have examined the influence of extraversion across cultures on the relationship between background sounds and cognitive performance, with most investigating a mainly Western sample group. In a part replication of Dobbs et al. (2011)'s study, Kou et al. (2018) investigated the effects of background noise and music on cognitive test performance in Chinese introverts and extraverts. In contrast to the results found by Dobbs et al. (2011), and other studies examining Western participants (Cassidy & MacDonald, 2007; Mistry, 2015), they found no differences in performance between the sound conditions (music, noise, and silence), and no interaction between extraversion and sound condition. This was postulated to be a result of habituation to noisy environments in Chinese participants, although other cross-cultural studies investigating the effects of background noise did not find any effects of habituation on cognitive test performance (e.g., Hellbrück et al., 1996). More pertinently, no previous study investigating the influence of extraversion on the relationship between background sounds and cognitive performance has looked at cross-cultural comparisons within the same study.

Aims and Hypotheses

The present study aimed to undertake a cross-cultural investigation into the effects of background sounds on cognitive test performance, and to investigate further the effects of extraversion on this relationship. It was a part replication of both Dobbs et al. (2011)'s and Kou et al. (2018)'s studies, and sought to validate their results using a similar Western (British) sample, and Asian (Singaporean) sample. We investigated whether auditory distractions (background music and noise) and personality (extraversion) had any effect on performance in three different cognitive tests: an abstract reasoning test, a verbal reasoning test, and a mental arithmetic test. Dobbs et al. (2011) employed a similar verbal reasoning test, while Kou et al. (2018) employed a

similar abstract reasoning and mental arithmetic test. Like Kou et al. (2018), one intelligence test was employed in order to control for IQ in participants.

Given that background sounds can influence arousal level, and introverts and extraverts possess different levels of arousal for optimal cognitive performance, introverts should perform worse than extraverts on cognitive tasks in the presence of background sounds. However, studies have found contradictory results when examining Western and non-Western (Asian) participants, as mentioned previously. As such, based on previous studies looking at Western (Dobbs et al., 2011) and Asian participants (Kou et al., 2018), it was predicted that the results obtained by Dobbs et al. (2011) would be replicated in the British sample, while the results obtained by Kou et al. (2018) would be replicated in the Singaporean sample. The hypotheses for the study are as follows:

> Hypothesis 1a: In the British sample, there will be a main effect of background sound for all three cognitive tests. The performance in each task is predicted to be the best in silence, followed by background music, and is worst with background noise.
>
> Hypothesis 1b: In the Singaporean sample, there will be no main effect of background sound for all three cognitive tests.
>
> Hypothesis 2a: In the British sample, there will be an interaction between the degree of extraversion and background sound for all three tests. Similar to Dobbs et al. (2011), a positive relationship between extraversion and test performance was predicted in the background music and noise conditions, but not in the silence condition.
>
> Hypothesis 2b: In the Singaporean sample, there will be no interaction between the degree of extraversion and background sound for all three tests.

Method

Participants

Ninety participants (42 males; 48 females) aged 18 - 36 years (M = 22.53 years, SD = 3.75 years) were recruited for the experiment via opportunity sampling. An a priori power analysis conducted using GPower 3.1 (Faul et al., 2009) suggested this was a sufficient sample size to detect a medium effect size (f^2 = .15) with a power of .80 (as recommended by Cohen, 1988) and an alpha of .05, as the sample size indicated was 85. Forty-five were British and 45 were Singaporean. Participants all possessed English as their first language. All participants consented to participate, and were compensated at a rate of £8/hour. Ethical approval was obtained from the appropriate Ethics Committee.

Materials

Sounds

The 'noise' track was mixed using Audacity (https://www.audacityteam.org) audio editing software running on a Windows 10 operating system. The noise samples included background chatter, computer-related sounds (e.g., keyboard typing), as well as environmental noise. The samples were downloaded from the websites Freesound (https://freesound.org) and SoundBible (https://www.soundbible.com). The length of the final track was 10:06 minutes, and simulated a typical office/study environment. The music was comprised of pop songs sung in English, as popular music is commonly heard on TV and radio, on various forms of new media (e.g., Spotify), and social networking sites such as YouTube in both the UK and in Singapore. Thus, the style of music would be familiar to both sets of participants. All songs were vocal, had a high tempo of around 120 beats per minute, considerable instrumental layering, and a neutral valence of around 0.5 as determined using the Spotify Web API. The songs chosen were "This Is What You Came For" by Calvin Harris featuring Rihanna, "New Rules" by Dua Lipa, and "Love Runs Out" by

OneRepublic. The length of the music track was 10:53 minutes. Both the noise and music tracks were played through a speaker placed in front of the participants. Decibel levels were measured and the noise and music tracks were played to participants at a constant level between 60 - 70 dB.

Tests

The tests were selected such that they were at a suitable difficulty level for all participants, and were similar to the tests used by Dobbs et al. (2011) and Kou et al. (2018):

1. *Advanced Raven's Progressive Matrices* Set II (Raven, 1990), which is an abstract reasoning test. The test consists of 36 items, each containing a figure with a pattern in it. Each figure had a missing piece, of which eight alternative pieces were presented, and participants had to indicate which piece they thought would complete the figure.
2. *Verbal Reasoning Test* composed of items from Bryon (2015). The test comprised of different questions: Antonym and synonym identification (selecting the antonym/synonym of the target word given several other options), sentence completion (identifying the option that best completes a given sentence), and grammar (picking the grammatically correct option given several other options).
3. *Mental Arithmetic Test* adapted from Lock (2008). The test consisted of 40 simple arithmetic questions. For each question, participants were required to conduct 10 consecutive calculations to arrive at the correct answer.

Personality

Participants completed the Big Five Inventory-2 questionnaire (Soto & John, 2017) in order to measure their degree of extraversion. The questionnaire comprised of 60 questions, with 12 questions relating to the extraversion subscale. Each item was rated on a five-point Likert scale

ranging from ‘strongly disagree’ to ‘strongly agree’. Soto and John (2017) reported a Cronbach’s alpha of .88 for the extraversion scale, and the value was found to be .85 in the present sample.

IQ Scores

The IQ test chosen was the Wonderlic Personnel Test (WPT), which is a test of general cognitive ability, and is administered in 12 min. The WPT is highly correlated with various measures of IQ, such as the Weschler Adult Intelligence Scale (Dodrill & Warner, 1988), as well as the Kaufman Adult Intelligence Test (Bell et al., 2002). The test consists of 50 items ordered in their difficulty, and includes word and number comparisons, disarranged sentences, serial analysis of geometric figures, as well as questions that require mathematical and logical solutions.

Procedure

Participants were randomly assigned to three separate groups, which had different task/background sound condition combinations. Within each group, the order of the tasks was also randomised. Participants were seated in a quiet room and completed each of the three tasks under a different sound condition. For each test, participants were given 10 minutes to accurately complete as many questions as possible. Following the three tests, participants completed the WPT and the BFI-2. Participants then completed a demographic questionnaire, and provided their age, gender, ethnicity and music preferences. In addition, participants were also asked: (1) whether they had heard the songs in the music track before, (2) their musical preferences (i.e., top five genre choices); and on a five-point Likert scale (ranging from never to always) (3) how often they study/work in noisy environments and (4) how often they listen to music while studying/working. Each testing session lasted approximately 1 hour.

Results

Our analytic strategy was to first explore our data by looking at the correlations between the variables within the total sample (N = 90) and then for each culture (N = 45 each). We then carried out the appropriate analyses of variance between personality types, cultures and distraction/background sound to test our specific hypotheses.

Initial analyses of results to check for normality for all variables found that the distribution of scores for the mental arithmetic test were positively skewed, and deviated significantly from a normal distribution using the Kolmogorov-Smirnov test, $D(90) = 0.12$, $p = .002$. The scores were thus transformed using a square root transformation to achieve a normal distribution of scores (Kolmogorov-Smirnov test: $D(90) = 0.09$, $p = .112$).

Correlations between extraversion, performance on the three tasks, and the Wonderlic scores were first examined. The correlation matrix presented in Table 1 shows that when examining all participants, there was a significant positive correlation between the three tests and the Wonderlic scores. However, a significant negative correlation was found between extraversion, performance on the Raven's test, and the Wonderlic scores. When examining both British and Singaporean participants separately (see Table 2), there was a significant positive correlation between the three tests and the Wonderlic scores.

Insert Tables 1 and 2 here

To avoid the loss of power associated with the dichotomisation of quantitative variables (such as extraversion) (see MacCallum et al., 2002), a standard multiple regression was employed to analyse the effects of extraversion and background sound on performance on the three cognitive tests, as well as the interaction between extraversion and background sound, rather than an ANCOVA. Before carrying out the analyses for each cognitive test, we checked for outliers (values

with standardised residuals > |3.0|) and found none. Analysis of collinearity statistics indicated that multicollinearity was also not a concern as VIF values were less than 10.0 (Field, 2005). For each cognitive test, a regression model was built with the predictor variables being background sound (dummy coded), and extraversion (continuous variable). Wonderlic scores were used as a covariate in the model, which also included an interaction term between extraversion and background sound. In the analyses comprising all participants, nationality was also included as a predictor variable, together with interaction terms between nationality and extraversion, nationality and background sound, and between nationality, extraversion, and background sound. Before analysing the performance of each test, extraversion scores were centred to allow for the effects of background sounds to be investigated at the mean extraversion level. The means for all participants, as well as for both British and Singaporean participants, are presented in Table 3.

Insert Table 3 here

Advanced Raven's Progressive Matrices Test Set II

All participants

There was a significant effect of Wonderlic scores on Raven's test performance, $F(1,77) = 51.89$, $p < .001$, $R^2 = 27.7\%$. There was no significant main effect of extraversion, $F(1,77) = 3.92$, $p = .051$, $R^2 = 2.1\%$. There were no significant effects of background sound, $F(2,77) = 1.14$, $p = .325$, $R^2 = 1.2\%$, no significant effect of nationality, $F(1,77) = 0.37$, $p = .547$, $R^2 = 0.2\%$, and no significant interaction between extraversion and background sound, $F(2,77) = 1.78$, $p = .176$, $R^2 = 1.9\%$. There was also no significant interaction between nationality and background sound, $F(2,77) = 0.61$, $p = .548$, $R^2 = 0.6\%$, no significant interaction between nationality and extraversion, $F(1,77) = 0.01$, $p = .912$, $R^2 = 0.0\%$, and no significant interaction between nationality, extraversion, and background sound, $F(2,77) = 1.85$, $p = .164$, $R^2 = 2.0\%$.

British participants

There was a significant effect of Wonderlic scores on test performance, $F(1,38) = 50.55$, $p < .001$, $R^2 = 46.6\%$. There was no significant main effect of extraversion, $F(1,38) = 3.21$, $p = .081$, $R^2 = 3.0\%$, and no significant effects of background sound, $F(2,38) = 0.76$, $p = .474$, $R^2 = 1.4\%$. However, there was a significant interaction between extraversion and background sound, $F(2,38) = 4.54$, $p = .017$, $R^2 = 8.4\%$. Simple effects analysis found that extraversion was a significant predictor of performance on the Raven's test in the silence condition, $F(1,13) = 6.28$, $p = .026$ ($\beta = -0.57$, $R^2 = 32.6\%$), but not in the noise, $F(1,13) = 0.08$, $p = .782$ ($\beta = 0.08$, $R^2 = 0.6\%$), and music conditions, $F(1,13) = 2.13$, $p = .168$ ($\beta = -0.38$, $R^2 = 14.1$).

Singaporean participants

There was a significant effect of Wonderlic scores on test performance, $F(1,38) = 11.05$, $p = .002$, $R^2 = 19.4\%$. There was no significant main effect of extraversion, $F(1,38) = 3.39$, $p = .074$, $R^2 = 5.9\%$. There were also no significant effects of background sound, $F(2,38) = 1.11$, $p = .341$, $R^2 = 3.9\%$, and no significant interaction between extraversion and background sound, $F(2,38) = 1.56$, $p = .223$, $R^2 = 5.5\%$.

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Verbal reasoning test

All participants

There was a significant effect of Wonderlic scores on test performance, $F(1,77) = 29.49$, $p < .001$, $R^2 = 22.9\%$. There was no significant main effect of extraversion, $F(1,77) = 1.10$, $p = .298$, $R^2 = 0.9\%$. There were no significant effects of background sound, $F(2,77) = 0.11$, $p = .897$, $R^2 = 0.2\%$, no significant effect of nationality, $F(1,77) = 0.33$, $p = .570$, $R^2 = 0.3\%$, and no significant

interaction between extraversion and background sound, $F(2,77) = 0.47$, $p = .625$, $R^2 = 0.7\%$. There was also no significant interaction between nationality and background sound, $F(2,77) = 0.43$, $p = .649$, $R^2 = 0.7\%$, no significant interaction between nationality and extraversion, $F(1,77) = 0.28$, $p = .598$, $R^2 = 0.2\%$, and no significant interaction between nationality, extraversion, and background sound, $F(2,77) = 0.05$, $p = .947$, $R^2 = 0.1\%$.

British participants

There was a significant effect of Wonderlic scores on test performance, $F(1,38) = 13.96$, $p = .001$, $R^2 = 23.1\%$. There was no significant main effect of extraversion, $F(1,38) = 0.33$, $p = .569$, $R^2 = 0.5\%$, no significant effects of background sound, $F(2,38) = 1.65$, $p = .205$, $R^2 = 5.5\%$, and no significant interaction between extraversion and background sound, $F(2,38) = 0.74$, $p = .482$, $R^2 = 2.5\%$.

Singaporean participants

There was a significant effect of Wonderlic scores on test performance, $F(1,38) = 15.42$, $p < .001$, $R^2 = 28.0\%$. There was no significant main effect of extraversion, $F(1,38) = 1.08$, $p = .306$, $R^2 = 1.9\%$, no significant effects of background sound, $F(2,38) = 0.16$, $p = .853$, $R^2 = 0.6\%$, and no significant interaction between extraversion and background sound, $F(2,38) = 0.47$, $p = .628$, $R^2 = 1.7\%$.

Mental arithmetic test

All participants

There was a significant effect of Wonderlic scores on test performance, $F(1,77) = 42.25$, $p < .001$, $R^2 = 27.9\%$. There was no significant main effect of extraversion, $F(1,77) = 3.15$, $p = .080$, $R^2 = 2.1\%$. There were no significant effects of background sound, $F(2,77) = 0.26$, $p = .770$, $R^2 =$

0.3%, and no significant effect of nationality, $F(1,77) = 1.20$, $p = .276$, $R^2 = 0.8\%$. However, there was a significant interaction between extraversion and background sound, $F(2,77) = 3.86$, $p = .025$, $R^2 = 5.1\%$. Simple effects analysis found that extraversion was a significant predictor of performance on the mental arithmetic task in the silence condition, $F(1,28) = 12.58$, $p = .001$ ($\beta = -0.56$, $R^2 = 31.0\%$), but not in the noise, $F(1,28) = 0.20$, $p = .657$ ($\beta = -0.09$, $R^2 = 0.7\%$), nor the music conditions, $F(1,28) = 0.52$, $p = .476$ ($\beta = 0.14$, $R^2 = 1.8\%$).

There was no significant interaction between nationality and background sound, $F(2,77) = 0.80$, $p = .454$, $R^2 = 1.1\%$, no significant interaction between nationality and extraversion, $F(1,77) = 0.00$, $p = .994$, $R^2 = 0.0\%$, and no significant interaction between nationality, extraversion, and background sound, $F(2,77) = 0.84$, $p = .436$, $R^2 = 1.1\%$..

British participants

There was a significant effect of Wonderlic scores on test performance, $F(1,38) = 24.37$, $p < .001$, $R^2 = 34.2\%$. There was no significant main effect of extraversion, $F(1,38) = 1.39$, $p = .246$, $R^2 = 1.9\%$, no significant effects of background sound, $F(2,38) = 0.89$, $p = .418$, $R^2 = 2.5\%$, and no significant interaction between extraversion and background sound, $F(2,38) = 1.05$, $p = .360$, $R^2 = 2.9\%$.

Singaporean participants

There was a significant effect of Wonderlic scores on test performance, $F(1,38) = 16.65$, p $R^2 = 6.0\%$, and no significant effects of background sound, $F(2,38) = 0.28$, $p = .754$, $R^2 = 0.8\%$. There was, however, a significant interaction between extraversion and background sound, $F(2,38) = 5.17$, $p = .010$, $R^2 = 15.0\%$. Simple effects analysis found that extraversion was a significant

predictor of performance on the mental arithmetic task in the music condition, $F(1,13) = 5.91$, $p = .030$ ($\beta = 0.56$, $R^2 = 31.3\%$), but not in the silence, $F(1,13) = 2.76$, $p = .121$ ($\beta = -0.42$, $R^2 = 17.5\%$), and noise conditions, $F(1,13) = 0.06$, $p = .818$ ($\beta = 0.07$, $R^2 = 0.4\%$).

Discussion

The results across both British and Singaporean samples revealed no significant main effects of background sound in any of the tasks, while a significant interaction between the degree of extraversion and background sound was only found in the mental arithmetic test in the Singaporean sample, but not for the other tests. Thus, in the British sample, hypothesis 1a was not supported across all tasks, while hypothesis 2a was significant only in the Raven's test although the direction of results was the opposite of what was predicted. In the Singaporean sample, hypothesis 1b was supported across all tasks, while hypothesis 2b was supported in all tasks except for the mental arithmetic test.

These results fail to support previous findings that found a difference between cognitive test performance in the presence of background sounds and in silence (Jahncke et al., 2011; Thompson et al., 2012). This is however in line with the results obtained by Furnham and Stephenson (2007), who failed to find any differences in cognitive performance between the music conditions and in silence. They suggested that this could have been due to participants being tested in a large group. Thus, the social situation in which the experiment took place could have caused a rise in participants' initial arousal level. As such, the music stimuli failed to induce a marked increase in arousal level in participants on top of the arousal gained from the social situation. However, in this study, participants completed the cognitive tests alone in a small room; hence, arousal resulting from the experimental social situation would have been minimal.

Background Sounds and Test Performance

A possible explanation for the failure to find a main effect of background sound on cognitive test performance is habituation to noise and/or music, which was first proposed by Kou et al. (2018). They postulated that this could have been due to larger class sizes of around 50 in China (OECD, 2012), as compared to the UK. As such, the Chinese participants in their study would have already been habituated to noise when studying in large classes in noisy school environments. Furthermore, studies by Banbury and Berry (1997) showed that when undertaking a memory task, habituation to background noise occurred in just 20 minutes, after which the disruptive effects of the noise were not found. Therefore, habituation to noise and/or music as a result of growing up and studying in large classes could explain why Kou et al. (2018) failed to find a main effect of background sound on cognitive test performance, while other studies employing Western participants managed to find this effect. As such, based on this explanation, the failure to find a main effect of background sound on cognitive test performance should only be seen in the Singaporean sample, but not in the British sample, as the average class size in Singapore (32.4) (Ministry of Education, 2018) is higher than that of the UK (24.5) (Department for Education, 2019). However, the failure to find an effect of background sounds on cognitive test performance is found in both the British and Singaporean participants. This thus indicates that class size may not be the best explanation for the potential effects of habituation to background sounds on cognitive test performance.

A more plausible theoretical explanation for the possible habituation in both British and Singaporean participants would be that of environmental noise levels participants to which they are exposed. All participants were sampled from large urban cities, namely London and Singapore. Both cities have high levels of noise pollution, with 27.0% of London's population living in areas

with an average noise level of more than 65 dBA (Department for Environment, Food, and Rural Affairs, 2019). In Singapore, the average noise level is 69.4 dBA, and 26.8% of the population living in areas with an average noise level of more than 70 dBA (Diong & Martin, 2017). Furthermore, high noise levels in classroom environments in schools in both London and Singapore have been found. In London, the average noise level found in classrooms was found to be 72 dB (Shield & Dockrell, 2004), while that in Singapore was found to be between 72 to 76 dB depending on where the classroom was located in the school (Wong & Jan, 2003). As such, participants could have already habituated to these noisy environments. Therefore, in this study, as participants were exposed to background sounds at decibel levels consistent with the environmental noise levels they would have been habituated to, this could explain why no differences in cognitive test performance across background sound conditions were found across both British and Singaporean participants.

In addition, 45.5% of all participants reported listening to music often when working and/or studying. Participants also reported listening to music for an average duration of 2.69 hrs a day. Furthermore, 71.1% of participants reported that they had heard at least two out of the three songs in the music stimulus, and 84.4% of participants reported that pop music was one of their top five musical genres. As the musical style employed in the study may have been familiar to most of the participants, and with many of them reporting that they listen to music often when working and/or studying, they may have become habituated to this type of music when undertaking cognitive tasks. This could potentially explain why participants in this study did not show a difference in cognitive test performance across background sound conditions.

Background Sounds and Extraversion on Test Performance

In this study, a significant interaction between extraversion and background sounds on cognitive test performance was only found in the Raven's task in the British sample. However, the direction of the finding was unexpected, as introverts only performed better in silence than extraverts, even though a relationship between extraversion and test performance was not predicted in the silence condition. Nonetheless, similar results were found in previous studies (Cassidy & MacDonald, 2007; Furnham & Allass, 1999), where introverts performed better in cognitive tasks in conditions of low arousal, like silence, as compared to extraverts. This unexpected finding from the current study can be explained via Eysenck's (1981) theory of optimal cortical functioning, and differences in arousal levels in introverts and extraverts in the British sample. In silence, the introverts' arousal levels could be at their optimum level of functioning due to the lack of external stimulation, which prevented introverts from being over-stimulated. However, the extraverts' arousal levels may not be at their optimum functioning level, as there is a lack of external stimulation causing them to be under-stimulated. As such, performance in the Raven's task would be better in introverts as compared to extraverts.

Other than the significant interaction found in the British sample for the Raven's task, results from this study failed to find an interaction between the degree of extraversion and cognitive test performance in the presence of background distractions across the cognitive tasks in both samples, and thus also fail to support previous findings (Cassidy & MacDonald, 2007; Dobbs et al., 2011). However, this is consistent with results from other studies, such as Kou et al. (2018), and Furnham and Strbac (2002), the latter finding that extraverts performed better than introverts on only one of the three cognitive tests they employed, which is similar to the present findings for the Singaporean sample.

There are several possible explanations for the failure to find any other significant interactions. The first concerns habituation and arousal. Zajonc (1968) first proposed that a familiar stimulus requires less attention, and thus arousal level would not increase with habituated stimuli. Schubert (1996) suggested that repeated exposure to music expressing the same emotion may lead to habituation. This has been empirically demonstrated in two experiments conducted by Schellenberg et al. (2012), where they found that when participants listened repeatedly to excerpts of music expressing a similar emotion, arousal levels did not increase. In the present study, as participants may already be habituated to the background sounds, the auditory stimuli employed may not have been sufficient to induce an increased arousal levels in extraverts to achieve an optimum arousal level, and may not have overstimulated introverts to exceed their optimum arousal level. This would explain why no differences in cognitive test performance were found between extraverts and introverts across different background sounds and in the verbal reasoning test and the mental arithmetic test in the British sample.

Secondly, potential differences in working memory capacity between extraverts and introverts could explain why a difference in performance was found between extraverts and introverts in the music condition only for the mental arithmetic test in the Singaporean sample. The mental arithmetic test is a working memory task (DeStefano & LeFevre, 2010), with all components of the working memory system (central executive, phonological loop, and visuo-spatial sketchpad) as proposed by Baddeley (1986) playing a role. Differences in working memory capacity have been found between introverts and extraverts, in particular the central executive component of working memory. The central executive component of working memory is thought to be located in the dorsolateral prefrontal cortex (DLPFC) (Cabeza & Nyberg, 1997). The DLPFC is influenced by the reticular formation in the brainstem, which is postulated as the anatomical

source of arousal differences associated with extraversion (Eysenck, 1967). Introverts possess a more active ascending reticular activating system, which results in a higher production of dopamine (DA) and higher DA levels in the DLPFC (Fischer et al., 1997). As higher levels of DA in the DLPFC have been found to impair working memory capacity (Arnsten & Goldman-Rakic, 1998), introverts would have a lower working memory capacity than extraverts, and would perform worse in working memory tasks requiring the central executive. This is demonstrated in a study by Lieberman (2000). In the study, participants took part in a memory-scanning task, which required them to remember a set of one to six digits. Participants were then shown another set of digits and were asked to indicate whether the digits were part of the set of digits they remembered. Results found that introverts performed worse in this task than extraverts, indicating that extraverts have a higher working memory capacity than introverts.

Clearly, these results merit replicating and extending. For instance, in this study, mainly Western music was played. Thus, it would be interesting for future studies to investigate the effects of culture-specific music, although this would mean it would differ in familiarity between groups, which would inevitably add other complications. Furthermore, as working memory capacity may present as a potential confounding factor, future studies should consider employing a measure of working memory capacity such as the complex span paradigm (Daneman & Carpenter, 1980), in order to examine the influence of working memory capacity, task complexity, and culture on tests of working memory in the presence of background sounds. Another line of research that should be pursued in further studies is to examine and measure cortical arousal in introverts and extraverts using neuroimaging methods, such as EEG. In particular, future cross-cultural studies should employ EEG to measure arousal levels, given theoretical and experimental evidence suggesting a difference in the basal arousal level between individuals in Western and Eastern societies (Kacen

& Lee, 2002; Lim, 2016). The current study has several limitations. Firstly, as with all studies involving music, the results are only generalisable to the specific music employed in this study, and potentially to other music in the same genre. Different types of music elicit different levels of arousal in individuals (Rickard, 2004), and the level of arousal differs based on an individual's musical preferences (Kreutz et al., 2008). Secondly, although arousal level played a key theoretical role in the current study, no direct measure of arousal levels in participants was obtained. The link between the degree of extraversion in individuals and their arousal level remains speculative (see Küssner, 2017, for a review), in light of several findings that showed no correlation between extraversion and cortical arousal levels in individuals (Beauducel et al., 2006; Schmidtke & Heller, 2004). Thirdly, we did not directly measure working memory capacity in participants, given that working memory capacity differs between extraverts and introverts, and this has been found to interact with background music to impact working memory task performance.

Research in this area has important implications for learning and working environments. We know that particular distractions like loud, familiar, and vocal music, or very loud, unpredictable and uncontrollable sounds impede concentration and learning, particularly for complex tasks. This has a greater impact on introverts though it is not clear if there are major cultural differences. On the other hand, music can energise and relax a person if they are doing less cognitively demanding tasks. Parents and teachers should then try to match the distraction to the task, realising that for some tasks the playing of any music would be a distraction. Further, there are times and places where educators and supervisors should ensure complete silence so that people are able to concentrate fully on particular tasks. However, we know that music can boost mood and there will be times when it should be used to do just that.

In conclusion, the present study aimed to investigate the effects of background noise and music on cognitive test performance in introverts and extraverts using Western (British) and Asian (Singaporean) samples, and sought to validate both Dobbs et al. (2011)'s and Kou et al. (2018)'s results through a part replication of their studies. No significant effects of background sound were detected in either the British or the Singaporean participants on any of the three cognitive tests. Further, no interaction between the degree of extraversion and background sound on performance was found on any of the tests in either sample, with the exception of the Raven's test in the British sample. Here introverts performed better than extraverts in silence, as they did on the mental arithmetic test in the Singaporean sample, whereas extraverts performed better than introverts in the presence of music. A potential explanation for the findings in terms of habituation to the environmental sounds, in particular the noisy urban environments participants were sampled from was proposed. Potential differences in working memory capacity between participants was also discussed. Future research could explore different auditory stimuli sets (cultural-specific music), investigate the effects of working memory capacity and culture on working memory test performance in the presence of background sounds, as well as measure cortical arousal across cultures using neuroimaging techniques like EEG.

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Table 1

The correlations between the measure of extraversion and cognitive abilities for all participants.

	Extraversion	Raven's	Verbal reasoning	Mental arithmetic
Raven's	-.256*			
Verbal reasoning	-.147	.506**		
Mental arithmetic	-.175	.512**	.350**	
Wonderlic (IQ)	-.248*	.687**	.594**	.636**

*$p < .05$. **$p < .01$.

Table 2

The correlations between the measure of extraversion and cognitive abilities for British and Singaporean participants.

	Extraversion	Raven's	Verbal reasoning	Mental arithmetic	Wonderlic (IQ)
Extraversion	–	-.077	.056	-.029	-.022
Raven's	-.291	–	.444**	.346*	.481**
Verbal reasoning	-.212	.431**	–	.241	.530**
Mental arithmetic	-.193	.564**	.337*	–	.545**
Wonderlic (IQ)	-.289	.739**	.543**	.645**	–

Note. Correlations for Singaporean participants ($n = 45$) are presented above the diagonal, and correlations for British participants ($n = 45$) are presented below the diagonal.

*$p < .05$. **$p < .01$.

Table 3

The adjusted mean scores and standard deviations for the three cognitive tests under background sounds (music, noise, silence) for all participants, British participants and Singaporean participants.

	Raven's		Verbal reasoning		Mental arithmetic	
	M	*SD*	*M*	*SD*	*M*	*SD*
All participants						
Silence	16.90	5.24	48.60	14.04	3.77	0.99
Noise	16.80	4.80	50.30	12.10	3.61	1.40
Music	17.27	5.71	48.50	13.79	3.66	1.11
British participants						
Silence	15.53	5.38	42.67	12.65	3.52	0.97
Noise	15.27	5.20	49.27	12.93	3.02	1.52
Music	13.67	5.16	43.53	12.96	3.60	1.25
Singaporean participants						
Silence	18.27	4.89	54.53	13.16	4.00	0.98
Noise	18.33	3.94	51.33	11.57	4.24	0.96
Music	20.87	3.62	53.47	13.15	3.72	1.00