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The Effects of Background Music on Cognitive Performance

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ABSTRACT

This study examined the effects of background music (BM) on students' cognitive performance. Thirty-six participants completed three cognitive tests: verbal reasoning (VR) (GL Assessment, 2020), digit-span (DS) (Richardson, 2007), and mental rotation (MR) (Vandenburg & Kuse, 1978). Each test was completed in one of the following conditions: silence, vocal music, and instrumental music. A latin-square design was used to assign each participant to a unique test/condition combination and order. The hypothesis was that instrumental music would enhance VR and MR performance, but would hinder DS performance, and that vocal music would be detrimental to performance across all tests. The first part of the hypothesis was based on the findings of Angel et al. (2010), which demonstrated background music's enhancement of cognitive performance, and Musliu et al. (2017), who found that music is detrimental to short-term memory tasks. Belsham and Harman (1977) showed that vocal music is detrimental to cognitive performance, forming the second half of my hypothesis. The hypothesis was fully supported: BM was detrimental to DS performance, whilst MR and VR performances were enhanced by instrumental music but hindered by the vocal music. Musicians and non-musicians were affected differently by the three conditions, as were those who usually work under different conditions.

1. INTRODUCTION

Background music (BM) refers to music that is played whilst the listener's primary attention is focused on another task (Racody & Boyle, 1988). Unlike the Mozart-effect (Rauscher et al., 1993), which refers to the enhancement of cognitive performance after listening to music, the BM-effect applies to immediate enhancement or hinderance of cognitive performance. Many students claim that BM helps them to study (Patton et al., 1983), however, despite considerable research into the cognitive effects of BM, conclusions are inconsistent (Schellenberg & Weiss, 2013).

Angel et al. (2010) concluded that BM is generally facilitating to cognitive performance. On the other hand, Sogin (1988) concluded that the music can be blocked out and is therefore irrelevant to task performance. Patston and Tippett (2011) divided participants into 'musicians' and 'non-musicians', and found that, whilst musicians perform better in silence than with BM, non-musicians are unaffected by it. Thompson et al. (2001) proposed an 'arousal' hypothesis suggesting that cognitive performance is enhanced by BM due to arousal, increased mood, and listener's enjoyment. These are all affected by the tempo and the mode (major or minor) of the music (Gabrielsson & Lindström, 2010). That BM might be detrimental has, however, also been explained by the 'cognitive-capacity hypothesis' (Kahneman, 1973), which posits that limited resources are available for cognitive processing at any given moment. Thus, BM can disrupt cognitive tasks when there is a potential for interference. In particular, detrimental effects related to BM seem to be modulated by task complexity: the more demanding the task, the stronger the detrimental effect of music (Furnham & Bradley, 1997). This theory may explain the inconsistent results within this field. When task complexity surpasses some critical threshold, then performance is impaired. Conversely, below that level, the arousal and mood hypothesis brings about positive performance effects in the presence of BM (Bottiroli et al., 2014). That said, with the use of different cognitive tests, it is hardly surprising that results are not consistent. For example, Angel et al. (2010) used the Criterion Task Set's Linguistic and Spatial tasks, Belsham and Harman (1977) conducted a picture comprehension task, and Patston and Tippett (2011) used language comprehension and visuospatial tasks created for the study. The variation in tests and stimuli are just two of many factors that could be at play in producing contradictory results between studies.

Therefore, to advance this area of research, I will compare the influence that BM has on three cognitive functions: short-term memory measured via digit-span performance (Richardson, 2007), visuospatial awareness measured via mental rotation performance (Vandenburg & Kuse, 1978), and linguistic ability measured via verbal reasoning performance (GL Assessment, 2020). By comparing between the tests directly, this study will give university students a clear idea of what type of work is best done with BM, and what type of work is best done in silence. The primary hypothesis for this study is that both BM conditions will be detrimental to short-term memory performance (DS), and that visuospatial and linguistic performance will benefit from the instrumental music but be hindered by the vocal music. My secondary hypotheses are as follows: any negative effects of BM will be more pronounced in the musicians than the non-musicians; any negative effects of BM will be lessened if the participant often works with BM; participants with a stimuli preference will perform worse than others; participants familiar with the stimuli will perform better than others.

2. METHOD

Design. The study employed a Latin square design (see Figure 1), which allows a control of variation in two directions: the pairing of tests with conditions and the order of the tests, which were combined to create a test unique to each of my thirty-six participants. The tests were labelled 1, 2 or 3, and the conditions were given letters ('S' for silence, 'I' for instrumental, and 'V' for vocal). The varying test order meant that fatigue and practice influences were eliminated. The independent variable of this study was the BM condition, and the dependent variable was performance.

123 VIS	132 VIS	213 VIS	231 VIS	312 VIS	321 VIS
123 VSI	132 VSI	213 VSI	231 VSI	312 VSI	321 VSI
123 ISV	132 ISV	213 ISV	231 ISV	312 ISV	321 ISV
123 IVS	132 IVS	213 IVS	231 IVS	312 IVS	321 IVS
123 SIV	132 SIV	213 SIV	231 SIV	312 SIV	321 SIV
123 SVI	132 SVI	213 SVI	231 SVI	312 SVI	321 SVI

Figure 1. Latin square design

Participants. Thirty-six participants (19 females) between the ages of 18 and 24 years participated in this study. The group comprised 21 musicians (those who can play an instrument to grade 5 standard) and 15 non-musicians. 12 of the participants stated they work with BM 'never', 12 stated 'sometimes', and 12 stated 'often'. Participants were recruited via the 'Overheard at Durham Uni' Facebook page, of which 65% of Durham University undergraduates are members.

Materials. This study employed a DS test (Richardson, 2007), an MR test (Vandenburg & Kuse, 1978) and an 11+VR test (GL Assessment, 2020). By testing three cognitive functions (numerical, visuospatial, and linguistic) the results will lead to a more accurate picture of overall cognitive performance.

Alongside silence, the musical stimuli used were:

Instrumental Music - Goosetaf's *Perpetual*

Vocal Music - Elgar's *Great is the Lord*

A pilot study contributed to the choice of stimuli. Also conducted on 'Overheard at Durham Uni', I asked for the genres of BM people listen to whilst working. I chose to use the two most popular genres for my study. 80% of participants disclosed that they listen to classical or lo-fi music whilst studying. One of the stimuli was to be instrumental and one vocal to measure the effect that lyrics have on cognitive performance. I chose a piece with English lyrics as it is the language common to all the participants, and it was crucial that the lyrics be meaningful for them to have the greatest effect (Jones et al., 1990 claimed that lyrics' semantic element is what causes their detrimental effect). Finally, the stimuli are longer than eight minutes so that, for the VR test, the music did not need to be repeated. All the stimuli were played through YouTube on participants' laptops. They were instructed to play the stimuli at a comfortable volume, preferably through noise-cancelling headphones. The informed consent was obtained by each participant before they began their tests and they completed a brief follow-up questionnaire, asking about musical ability, working habits (with/without BM), whether they liked/disliked either stimulus and whether they recognised either stimulus.

Procedure. Participants completed the tests in their own homes due to restrictions on social contact at the time of research. An email containing a consent form, information sheet, an instructions page, and links to the tests and to the YouTube stimuli was sent to each participant. The test/condition pairings and the order in which to complete the tests were also included. Participants then completed the three tests (DS, MR, and VR) under the specified conditions (silence, vocal music, and instrumental music) in the stipulated order, recording their scores as they went. After completing all three tests, participants completed the questionnaire, and finally emailed me their scores. The analysis includes descriptive data presented using means, standard deviations, and 95% confidence intervals. *T*-tests and ANOVAs were used to compare means between the groups. All *p*-values are two-tailed with a significance level of < 0.05. The data were analysed in Microsoft Excel.

3. RESULTS

The DS result was the maximum number of digits the participant could successfully remember. The MR test presented the participants with their overall percentage accuracy (%) as well as their mean time taken per question in seconds (t=time). To include speed and accuracy in the analysis, these values were combined for an 'MR score' (%/t). The VR performance was measured by the number of correct answers in the time allocation.

My primary hypothesis was fully supported by the results shown in Figures 2-4. Participant performance in the DS test was hindered by BM (Figure 2). Performance in both the MR and VR tasks was enhanced by the instrumental music but hindered by the vocal music (Figures 3 and 4). By dividing the participants into groups dependent on the characteristics they disclosed in the questionnaire, some interesting conclusions about the interaction of BM and cognitive performance come to the fore.

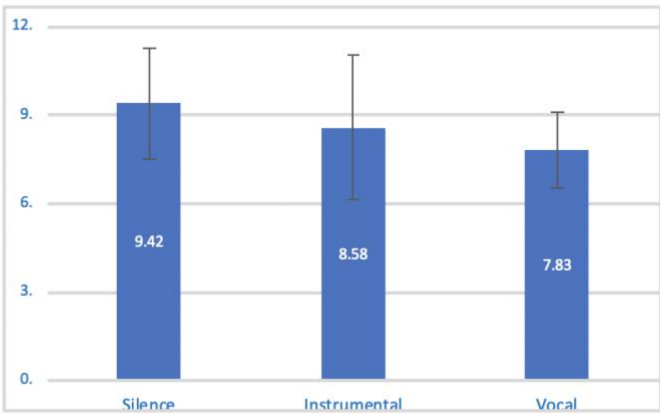

Figure 2. Effect of background music on digit span performance

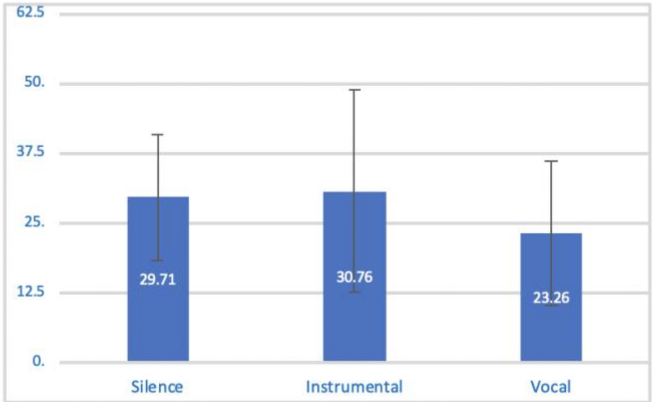

Figure 3. Effect of background music on mental rotation performance

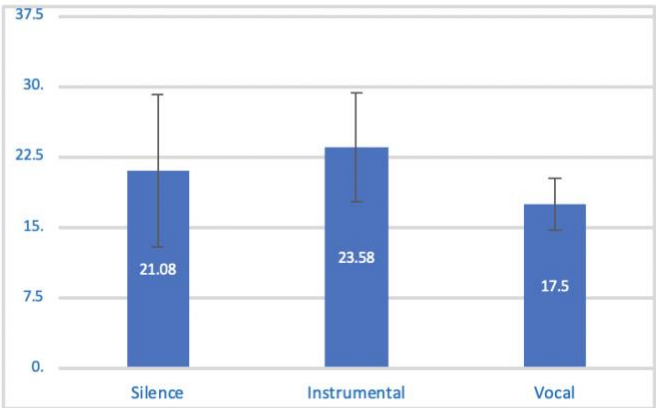

Figure 4. Effect of background music on verbal reasoning performance

Table 1 compares the performance of musicians and non-musicians. A *t*-test and ANOVA were run on the data with the *p*-values presented in the final column. In the DS test, the groups' performance was affected similarly by the presence and type of BM. Interestingly, whilst their reaction to the different stimuli was uniform, the musicians scored higher than the non-musicians across all conditions. In the MR test, the musicians performed best under the instrumental music condition, whilst the non-musicians performed best in silence. Both groups, however, exhibited a decrease in performance under the vocal music condition. The VR test also revealed weakest performance under the vocal music condition for both groups. As in the DS test, the musicians and non-musicians responded similarly to the conditions. The difference in verbal reasoning performance between those who listen to background music varying amounts was statistically significant ($p = 0.041$).

Table 2 compares the performance of those who listen to BM 'often', those who listen 'sometimes', and those who 'never' listen. The DS results show those who never work with BM perform best in the silent condition, and the same was seen in the MR test. They were most acutely affected by the presence of BM. In the MR test, those who listen to BM often scored very similarly across the conditions, but much better than the other two groups. In the VR test the performance of the group who often listens to BM under the instrumental condition was significantly superior to the other groups' performance under any of the three conditions.

Table 1. Effect of BM on Cognitive Performance of Musicians vs. Non-Musicians

COGNITIVE TEST	CONDITION	Musicians (95% CI)	Non-Musicians (95% CI)	p-Value
DIGIT SPAN	Silence	10 (6.96-13.04)	9 (7.69-10.30)	p = 0.057
	Instrumental	9 (6.7-11.54)	7.5 (6.58-8.42)	
	Vocal	8.3 (7.38-9.11)	7 (4.75-9.25)	
MENTAL ROTATION	Silence	25 (16.45-33.82)	39 (27.69-50.01)	p = 0.295
	Instrumental	31 (12.81-49.51)	30 (16.78-43.12)	
	Vocal	19 (6.62-30.74)	27 (13.02-40.04)	
VERBAL REASONING	Silence	21.38 (13.47-29.28)	20.5 (11.09-29.91)	p = 0.119
	Instrumental	22.6 (18.43-26.77)	24.29 (17.64-30.93)	
	Vocal	16.88 (15.74-18.00)	18.75 (11.59-25.91)	

Table 2. Effect of BM on Cognitive Performance of Those Who Work With Background Music 'Often', 'Sometimes 'and 'Never'

COG TEST	COND-ITION	Often (95% CI)	Sometimes (95% CI)	Never (95% CI)	p-Value
DS	Silence	9.33 (4.16-14.5)	9.33 (3.6-15.07)	9.5 (7.43-11.57)	p = 0.279
	Instrumental	7.67 (6.23-9.10)	9.6 (5.16-14.04)	8 (5.75-10.25)	
	Vocal	8.33 (7.06-9.60)	8 (6.7-9.3)	6 (6-6)	
MR	Silence	34.33 (7.78-60.88)	22 (13.89-30.11)	18 (0-43.41)	p = 0.198
	Instrumental	33.98 (7.53-60.43)	20.33 (7.59-33.08)	21.83 (17.07-26.59)	
	Vocal	34 (0-78.26)	17 (15.24-18.76)	15.75 (14.22-17.27)	
VR	Silence	21.5 (9.78-33.22)	24.54 (8.85-40.23)	32.7 (16.68-48.72)	p = 0.041
	Instrumental	30.33 (22.35-38.32)	27.78 (18.21-37.34)	27.05 (0-144.5824)	
	Vocal	20.67 (11.26-30.07)	11.13 (0.5-21.68)	23.95 (14.8-33.06)	

I combined the results of those who expressed an opinion about the music (who either particularly liked or disliked it) and those who did not. I have also given each participant a cumulative score by adding up their DS score, MR score and VR answers. These are the values used in Figure 5. Regarding those who were familiar compared to those who were unfamiliar with the stimuli, there was only a small difference of < 0.3.

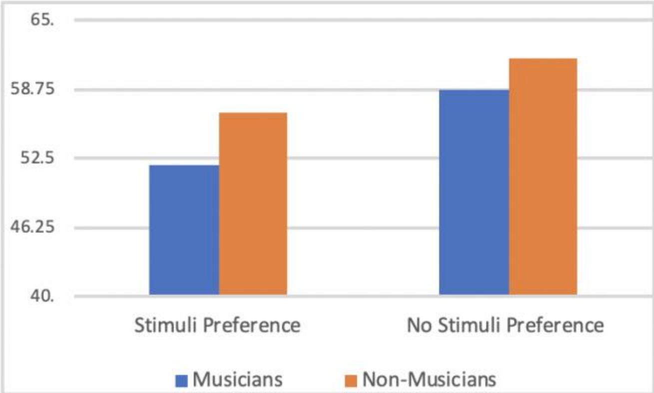

Figure 5. Effect of stimuli preference on cognitive performance

4. DISCUSSION

Overall the results support the primary hypothesis that the DS performance would be hindered by BM, and that the MR and VR performance would be enhanced by the instrumental music, but hindered by the vocal music. Therefore, BM can be beneficial to cognitive performance, but it is dependent on the cognitive function at work and the type of music. This finding is important for students who are unsure about whether BM is beneficial to their learning. This conclusion supports Angel et al. (2010)'s findings that BM is generally facilitating to cognitive performance but qualifies it by adding that it is dependent on the aforementioned factors. It also, therefore, supports the ostensibly contradictory findings of Musliu et al. (2017), which state that BM is detrimental to the cognitive function specific to short-term memory.

It is interesting to consider the participants' self-awareness. The follow-up questionnaire asked whether they felt the BM was beneficial, detrimental, or futile. Nineteen of the 36 participants felt that the vocal music was detrimental, 17 did not think it made a difference, and 0 found it helpful. Eighteen participants felt that the instrumental music helped, 18 felt it did not make a difference, and 0 found it detrimental. Whilst the participants' perceptions are not wholly consistent with the study's results, the sense that the instrumental music was helpful and the vocal music detrimental is consistent with two of three of the tests' results. The largely accurate account refutes Sogin's (1988) theory that BM is often just blocked out as, in order to recognise its effect, BM must be engaged with.

In the DS and VR tests, BM affected the musicians and non-musicians very similarly, which contradicts both Patston and Tippett (2011)'s suggestion that they might be affected differently, and my hypothesis. It is possible that differing criteria to classify a musician from a non-musician led to this contradiction. The musicians from Patston and Tippett (2011) had all performed music at university or nationally and almost all played more than one instrument, whilst the non-musicians had fewer than four years of musical training. This study's musicians were of at least a 'Grade 5 standard' on at least one instrument and the non-musicians were the remaining participants. There was therefore a greater difference in musicianship between the musicians and non-musicians in Patston and Tippett's study than in the present study, which may have led to the latter's less polarised results. That said, what is striking about the DS performance is that the musicians outperformed the non-musicians across all conditions. That musicians have superior short-term memory to non-musicians was a theory tested by Talamini et al. (2018), though it is unclear whether individuals with better memory are more likely to become musicians or if a better memory is a consequence of musical training. It is likely that both factors are partially responsible.

Regarding the comparison between those who listen to BM often, sometimes, and never, a larger sample size is needed to come to a conclusive result, though it is clear that those who never use BM were affected more acutely by it than the other two groups. This resonates with Sogin's (1988) theory that the music is blocked out, as perhaps the non-listeners are simply less practised at blocking the distraction out than the rest of the participants. It is worth mentioning that the choice of BM for this study may not reflect the BM that would be chosen by the participants and, hence, the conditions don't fully reflect the natural working environment of the participants. A further pilot study would allow participants to choose from a series of stimuli which they would most likely listen to in order to allow the working environment to be more accurately replicated.

My results regarding the stimuli preferences of the participants support the findings of Anderson and Fuller (2010). They are, therefore, contradictory to the 'arousal and mood' hypothesis of Thompson et al. (2001). Every participant who reported having a preference stated particularly liking the instrumental music, and this group performed worse than the group with no opinion about the music, in accordance with my hypothesis. The former group were perhaps enjoying the music too much and not focusing on the task at hand. Across both groups, the musicians' performance was inferior to the non-musicians', which resonates with Kahneman's (1973) 'cognitive-capacity' hypothesis. Musicians may have been allocating a greater cognitive capacity to the music as they engaged with the music more deeply than the non-musicians, resulting in a poorer performance.

The difference in performance between those familiar with the stimuli and those unfamiliar with them was negligible, which is inconsistent with both the findings of Hilliard and Tolin (1979), who concluded that familiarity with BM enhanced task performance, and my hypothesis. The lack of a clear result in comparing these groups is most likely a reflection on the small sample size.

The small sample size of thirty-six may have skewed other results too. Within the Latin square design (Figure 1), the small squares only represented one participant, which meant that results could be easily influenced by very few outliers. A larger sample size would have led to more reliable results which would be more valuable for university students who are unsure about the optimal working conditions. A further limitation of this study is that participants may have found one of the tests easier than the others, and hence found it easier to complete that test in the presence of music, as might be suggested by Kahneman's (1973) 'cognitive-capacity' hypothesis. To minimise the chances of this, it would be possible to run a pilot study which saw participants complete all three tests in silence and a questionnaire about how demanding they found each test on a scale of 1-5. If one test was overwhelmingly easier or harder than the others, it could be revised. A third limitation faced by this study is that the musical stimuli exemplified not only instrumental/vocal music, but also different genres: lo-fi and classical. It is possible, therefore, that the effects of the vocal music were as a result of its classical quality rather than the presence of lyrics, and the same can be said for the instrumental music. I suggest that this is unlikely to be the case due to the literature suggesting that lyrics and, more specifically, meaningful lyrics, are detrimental to cognitive performance (Belsham & Harman, 1997; Jones et al., 1990). That said, future studies would benefit from keeping the genre consistent in order to discern whether it is the genre or lyrics affecting the participants' performance.

This study has shown the effects of BM on the performance of different cognitive functions in university students, and has concluded that BM can be advantageous, but only under specific circumstances. Short-term memory has proved to be obstructed by BM, but visuospatial and linguistic task performance was enhanced by instrumental BM. This study suggests that the existing literature is less contradictory than it seems. Further research of a similar kind would be highly valuable to the field, ideally research with a larger sample size in order to attain statistically significant results. Tightly controlled conditions would be beneficial, as social restrictions meant that the tests were completed with varying degrees of distraction. Control of external factors such as these would result in more reliable conclusions. A potentially fertile area touched on was the idea of BM listeners being affected differently to those who work in silent conditions. Though beyond the scope of an undergraduate project due to temporal restrictions, it would be interesting to monitor two groups of participants over time: one who works with BM and one who works in silence, testing them regularly to measure the effects of the conditions over time.

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