The effect of Self-selected background music on spatial reasoning ability—an extension of the Mozart effect

Weihang Zhang

University of Macau, Macau 999078, China

SC02229@connect.um.edu.mo

Abstract. The Mozart effect is a phenomenon where exposure to classical music leads to improved spatial reasoning ability test scores. This effect is linked to the mood and arousal state of listeners. The hypothesis proposes that any music genre can enhance spatial reasoning ability provide it arouses positive affective states. The current study used a within-subject design to collect data from 30 participants who took spatial reasoning tests in silence and with self-selected background music (BGM). Results show that BGM significantly improves spatial reasoning ability, mediated partly by arousal and fully by mood. The study concludes that self-selected BGM can facilitate spatial reasoning by activating positive mood and improving arousal status. The result also confirms that self-selected BGM can improve mood and arousal status of an individual.

Keywords: Background music, Mozart effect, Spatial reasoning, mood, arousal

1 Introduction

The practice of listening to background music (BGM) during study sessions is a common behavior observed among college students [13]. In fact, a considerable number of students across all educational levels, ranging from elementary to graduate school, have been reported to engage in this practice [13]. Notably, a subset of college students has been found to devote as much as 90% of their available study time to listening to music [1]. Despite the widespread adoption of this practice, it is currently unclear whether the act of listening to music during study sessions can improve cognitive performance across a broad range of domains. Several studies have investigated the impact of background music (BGM) on cognitive processes within the domain of language cognition. BGM has been shown to facilitate foreign language writing [3] and language learning [16], although it can have an inhibitory effect on the retention of literacy concepts [17] and the recognition of Chinese characters [18]. In the domain of memory, the effects of BGM appear to be either hindering or non-existent on memory encoding or retrieval across a variety of contexts [4] [6][21] [22].

The enhancement of an individual's spatial reasoning ability has long been a critical topic of investigation within the field of cognitive ability. A seminal experiment conducted by Rauscher, Shaw, and Ky (1993) [24] reported that college students exhibited

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better performance on standardized tests of spatial abilities following exposure to a Mozart sonata as compared to relaxation instructions or silence. This phenomenon, commonly referred to as the "Mozart effect," sparked a decade-long debate regarding the validity of this claim. Despite the initial findings, subsequent studies have reported mixed results regarding the efficacy of music in enhancing spatial reasoning ability. Hetland (2000) [10] and Hernando-Requejo (2018) [11] argued that listening to classical music may indeed enhance spatial reasoning, while McKelvie and Low (2002) [19] found no significant effect between music and spatial reasoning in children. Furthermore, Waterhouse (2006) [28] suggested that the results of Rauscher's study were not replicable. In an attempt to reconcile these conflicting findings, Thompson et al. (2001) [27] proposed that the Mozart effect may be an artifact of arousal and positive mood. Specifically, they found that the positive mood induced by the music was responsible for the observed improvement in spatial reasoning ability. Additionally, other research has suggested that music can induce an ideal level of arousal, which can aid in utilizing an efficient selective attention approach [26]. Taken together, these findings suggest that the relationship between music and spatial reasoning ability is complex and context-dependent.

While some researchers have focused their efforts on investigating the underlying mechanisms of the Mozart effect, others have drawn attention to the importance of music characteristics and individual preferences in mediating the cognitive effects of background music (BGM). Waterhouse (2006) [28] conducted a review of ten studies analyzing the impact of listening to Mozart's music prior to engaging in visual-spatial tasks. Her review identified contradictory findings across studies and proposed that the beneficial effects of BGM may be due to the emotional arousal it induces, providing short-lasting improvements in learning. Moreover, Hallam and MacDonald (2016) [8] conducted a meta-analysis of studies published between 1965 and 2008 with findings that several studies reported positive effects of BGM on cognitive performance, and that these effects were often modulated by the characteristics of the music and participants' individual music preferences. In sum, these findings suggest that the relationship between BGM and cognitive performance is multifaceted and influenced by a range of factors, including music characteristics and individual preferences.

According to Gonzalez and his colleagues' findings, the "arousal effect"-which refers to the enhancement of spatial reasoning performance through the generation of arousal and mood – is not significantly different between Mozart's music and other stimulating activities [7]. This suggests that the type of music played is not the central feature of the Mozart effect, rather, any activity that generates arousal and mood may have the potential to enhance spatial reasoning ability. Moreover, studies also found a correlation between self-selected music and task performance with an unknown mechanism. Cassidy and MacDonald (2009) [2] found when listening to self-selected music, individuals perceived lowest distraction, highest enjoyment, liking and appropriateness driving games. The study tried to explain the phenomenon through affect and arousal modification, which is similar with Thompson's (2001) conclusion: mood and arousal will enhance cognitive function [27]. Moreover, the conclusion proposed that self-selected music can also be as the role generating arousal. Thus, there are two hypothesizes:

1. Self-selected BGM can facilitate spatial reasoning ability because the ability is also included in cognitive functions.
2. Self-selected BGM can improve individuals' mood and arousal to make them perform better in spatial reasoning tasks.

2 Material and procedure

2.1 Participants and materials

Participants: 30 aged 18 to 22 university students were recruited from the University of Macau. Some Descriptive factors were recorded.

Materials: (1) Spatial reasoning tasks: tested by Raven's Progressive Matrices [25], the form got five separate parts, and each part has 12 questions. Divide the questions into two groups based on odd and even question numbers in each part. (2) The assessment of arousal and mood can be conducted using the Profile of Mood States (POMS) developed by McNair et al. in 1992 [20], which comprises a list of 40 5-point descriptive adjectives pertaining to emotional states and mood. Referring to Thompson (2001), adjectives in Vigor-Activity subscales are referred to as positive arousal or POMS arousal; adjectives in Depression-Dejection subscales are referred as negative affect or POMS mood [30]. The whole scale was used to increase validity. (3) Music stimuli: To achieve higher level of ecological validity [24], 30 participants were told to provide a playlist of their favorite music with a duration of at least 20 minutes and sent it to experimenters. The purpose of this was to obtain music that participants typically enjoyed listening to while engaging in self-learning or reading in their daily lives. For those participants who did not usually listen to music during studying, we instructed them to provide music selections that they found tolerable while taking test. This process was designed to gather familiar and enjoyable music for use in the experiment, which aimed to investigate the effects of music on spatial reasoning.

2.2 Procedure

The study employed a within-subject design to mitigate the influence of extraneous variables caused by individual differences. Instructed by the experimenters, a group of 30 participants were tasked with creating a playlist comprising their preferred music, with a minimum duration of 20 minutes. Following this, the participants were required to submit their playlist to experimenters, complete a matrix on a laptop, and listen to the same volume. The study consisted of two conditions: the first favorite music while completing the matrix, and the second being the silence condition, where participants completed the matrix in a silent environment. To counterbalance the order effects, half of the participants were randomly assigned to start with the silence condition, while the rest started with the music condition. To minimize the impact of practice and fatigue effects, a two-week rest period was enforced between the two conditions, during which participants were not given any other spatial reasoning tasks to complete [12].

In music condition, participants were told to listen to their self-selected music for 5 minutes and then finish the POMS questionnaire, while in silence condition, they were

told to close eyes and stay calm for 5 minutes. After answering POMS questionnaire, there are 30 questions examining spatial reasoning ability in each set and participates used 8 minutes to answer them, the score was recorded and standardized.

3 Analyze and result

To verify the first hypothesis, researchers utilized a one-way ANOVA to examine the impact of background music (BGM) on spatial reasoning ability, while excluding the effects of POMS arousal and mood. The results showed that BGM had a significant effect on spatial reasoning, as evidenced by a significant $F(1,59) = 11.637$, $p < .05$. Regarding the verification of the second hypothesis, two parts were involved. Firstly, a one-way ANOVA was used to investigate the effects of BGM on both mood and arousal. It was found that BGM had a significant impact on both arousal and mood, as evidenced by $F_{arousal}(1.59) = 8.629$ and $F_{mood}(1,59) = 25.160$, both $p < .05$. Secondly, researchers examined the correlation between mood, arousal and spatial reasoning. In the presence of music, a significant correlation was found between arousal and spatial reasoning ability, with a Pearson correlation of .412 and a p-value of .024, as well as between mood and spatial reasoning, with a Pearson correlation of .372 and a $p = .043 < .05$. In the silence condition, significant correlations were also observed between arousal and spatial reasoning and between mood and spatial reasoning, with Pearson correlations of .365 and .395, respectively, and p-values of less than .05.

To investigate the role of mood and arousal, researchers conducted a mediation analysis. The results showed that there was a partial mediation effect of arousal, with a p-value of .101 and a significant effect of BGM on spatial reasoning, with a p-value of .039. In contrast, for mood, a significant mediation effect was observed, and mood fully mediated the relationship between BGM and spatial reasoning ability, with a p-value of less than .05.

In summary, the data demonstrated that self-selected BGM had a significant impact on spatial reasoning ability, arousal and mood separately. Furthermore, mood had a full mediation effect on the relationship between BGM and spatial reasoning, while arousal had a partial mediation effect. Finally, both mood and arousal status had a significant influence on spatial reasoning performance, indicating that high activation levels of both mood and arousal corresponded to stronger spatial reasoning ability.

4 Conclusion and discussion

Despite the diverse array of musical genres encompassed by self-selected music, research has indicated a noteworthy correlation between self-selected music and spatial reasoning. Moreover, the findings effectively corroborate the notion that BGM can exert a discernible influence on cognitive processes beyond the realm of music education, as posited by Hallam and Macdonald in their 2016 study [9]. Meanwhile, the current research proved the hypothesis that arousal and mood will facilitate the spatial reasoning ability under self-selected background music environment no matter the musical tempo or mode [14] or music genres [5]. At the same time, it is also proved that self-

selected BGM can significantly affect mood and arousal status of an individual, which is consistent with the hypothesis.

Although there is no significant or observable mediation effect of arousal on the relationship between self-selected BGM and spatial reasoning ability, various research has demonstrated that mood or emotion will significantly affect arousal status under music condition [15] [22] [23], which means there may underly a more complex relationship among mood, arousal and self-selected BGM and spatial reasoning, further research will be conducted to test other possible relationship among those factors.

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