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The Effect of Background Music with Lyrics on Human Decision-making Performance of Mental Arithmetic Task

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Abstract: *Music is frequently played in human daily-life, people always make decisions in the background music environment. This study conducts an online experiment questionnaire, made up of mental arithmetic questions and Positive and Negative Affect Schedule scale (PANAS), focuses on lyrics effect on decision-making and corresponding emotional arousal level. The results were based on the mental arithmetic task performance speed and accuracy rate to demonstrate participants made decisions slower but with no significant accuracy difference under background music with lyrics. Further exploring the gender difference in decision-making performance found females are more strongly influenced by lyrics than melody condition that they become much slower under lyrics background music, compared with males.*

Keywords: *Background music, emotion lyrics, melody, decision-making, mental arithmetic task, speed, accuracy, male, female*

1. Introduction

Music holds a pervasive presence in nearly all aspects of human life, accompanying individuals across various activities such as learning, working, and physical exercise. Campbell, Connell, and Beegle [2] assert, after a comprehensive examination of the extensive literature on music, that popular music possesses its unique aesthetic and societal values, with considerable potential to resonate with the daily lives of adolescents. However, the influence of music extends beyond the adolescent experience, permeating the lives of individuals within society. Research has shown that in open-plan office environments, people express a subjective preference for background music as a mean to counteract environmental noise. Background music serves as a continuous auditory backdrop, without detrimental effects on worker performance while masking intermittent environmental noise [21]. Consequently, the impact of background music on the executive function of cognitive activities has garnered substantial attention.

Prior research has revealed conflicting findings regarding the effects of background music. On the one hand, some studies have demonstrated its adverse impact on workplace attention control [8], while others have highlighted its potential to enhance cognitive performance, particularly in tasks characterized by low cognitive load [12] [6]. The Arousal-Mood Theory posits a relationship between an individual's emotional states and their level of physiological arousal, suggesting that heightened physiological arousal can lead to more robust emotional experiences, which may, in turn, influence decision-making processes.

Furthermore, commercial businesses and retailers frequently employ background music in stores and in advertisements to evoke emotional responses and influence purchasing behavior [17], underscoring its significance in decision-making contexts. Background music has thus evolved into a prominent modality and is considered a distinct element within psychology.

Background music comprises various components, including tempo, musical genre, and mode, leading scholars to encounter numerous variables within different demographic contexts.

Tempo, for instance, has been a focal point in prior research on the impact of music on decision-making. Studies by Day et al. [3] and Perez Santangelo et al. [20] have highlighted its influence. Fast-tempo

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music, characterized by a brisk pace and upbeat rhythm, has been found to elevate mood and induce high arousal states, resulting in quicker decision-making and a propensity for risk-taking [8] [15]. Conversely, slow-tempo music, marked by a soothing and relaxed pace, tends to calm individuals' moods, leading to a more cautious approach to decision-making.

In practical applications within businesses and organizations, the intensity and duration of background music are strategically employed. Businesses may opt for high-intensity music to stimulate customer engagement and encourage longer shopping durations, while longer-duration music may be chosen to foster a relaxed shopping atmosphere. Research has shown that the intensity and duration of background music can significantly impact individual's emotional state and level of arousal, subsequently influencing their behavioral responses [21] [24].

Music lyrics have also garnered attention from scholars investigating their influence on human behavior. Schuldt and Silverman [22] have suggested that lyrics can affect driving behavior by evoking a wide range of emotions and affecting cognitive load. In psychotherapy, mental health professionals frequently utilize music with lyrics as a therapeutic tool [11]. However, the impact of background music with lyrics on human decision-making remains a subject that merits further exploration.

Previous research has primarily focused on background music as either a distractor of attention or an inducer of emotional arousal within specific demographic groups or general personality characteristics. However, fewer studies have investigated the effects of music lyrics, particularly in relation to potential gender differences in the context of background music's influence on human decision-making. This gap exists despite clear distinctions in terms of accuracy and speed in cognitive task performance.

This study seeks to address several questions. To what extent does the presence of lyrics in background music affect speed and accuracy in mental arithmetic tasks when compared to background music without lyrics? We are particularly interested in exploring potential gender differences in these effects, while also considering the role of emotional arousal. To investigate these questions, the current study has designed an online experiment involving a mathematical question test with a time constraint, administered alongside the same pop song presented in two versions—one with lyrics and one without. We assume decision-making is primarily a visual task, and we evaluate response seed and accuracy accordingly. Through statistical analysis of the collected data, this study endeavors to advance our understanding of the impact of lyrics on cognitive activities, particularly within the context of human decision-making behavior and any potential gender-related distinctions.

2. Literature review

2.1 Decision-making and Music

Background music is recognized as a potent influencer of human emotion and mood across various cultural contexts. It is generally understood that fast-tempo music in major keys tends to evoke positive emotions, while slow-tempo music in minor keys can elicit negative emotions [19]. Background music has the capacity to affect individuals' physiological responses and even prompt motor reactions based on subjective feelings, impacting both top-down and bottom-up cognitive behaviors. Decision-making, historically conceptualized as a normative mode of rationality, involves the processing of information and adhering to decision policies that accumulate evidence for making choices. Scholars commonly employ Reaction Time and Accuracy as measures to assess the decision-making process [13] [16].

The role of emotion in decision-making has prompted research into factors influencing individual emotional responses. Contemporary studies have investigated emotion as a crucial element in information processing, with music emerging as a fundamental variable with robust effects. Day et al. [3] conducted a study in which they explored the effects of background music tempo on the performance of multi-attribute decision-making tasks. They trained participants to employ two decision-making strategies—weighted additive rule and elimination-by-aspects method—and recorded participants' decisions through eye movements to measure decision time and information processing speed. Their analysis revealed that faster tempo music led participants to use more intra-dimensional search, increasing information load and ultimately improving the accuracy of more challenging decision-making tasks. This suggests that the speed of information processing is influenced by music tempo.

2.2 Emotional Effects of Music

Music has been recognized both as an emotion arousal inducer and a distractor in cognitive processes

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[14]. Recent research by Perez Santangelo and colleagues [20] demonstrated that background music can lead individuals to make less cautious decisions. Using decision tasks with observable outcomes, they found that task speed and accuracy were affected by slower and faster D minor background music compared to silence. Faster D minor background music was associated with a negative mood, resulting in faster but less accurate decision-making. This suggests that background music can serve as a distractor in cognitive activities.

The role of attention as a limited resource in cognitive processes is widely acknowledged. According to load theory of attention, the distribution of attention can vary depending on task difficulty. In easier tasks requiring lower processing capacity, individuals are more susceptible to distraction by external stimuli [7].

2.3 Role of Lyrics

While tempo has been a central component in research on background music, many individuals typically listen to music with lyrics. Lyrics, conveying semantic information, represent one of the most practical elements in background music research. Galizio and Hendrick [9] studied folk songs and found that lyrics could significantly enhance positive emotional arousal, as lyrics conveyed semantic information alongside the music melody. Similarly, lyrics can also amplify negative emotions, such as sadness or anger, by conveying negative semantic information [1]. This has led to the frequent use of lyrics in psychological clinical settings, as lyrics are not only a component of music but also convey meaning.

Research has explored whether individuals pay attention to lyrics or process their meaning in conjunction with the melody. Pei Hsuan Chien and Chan [18] conducted an event-related potential study on lyrics processing and found that lyrics were automatically processed for their meaning, whether individuals listened to and old or new song. This suggests that the perception of music with lyrics involves spontaneous access to both melody and semantic input, indicating that lyrics can influence human behavior.

The impact of lyrics on decision-making, particularly in conjunction with music, remains relatively unexamined. To address this, Karageorghis and his team [11] conducted a study isolating music melody and lyrics during urban driving tasks. Their findings suggested that lyrics may have a distracting effect, particularly for females, leading to increased heart rates during urban driving.

2.4 Gender Differences in Emotion Arousal

Gender differences in music preferences have been well-documented, with girls often favoring popular music and boys preferring rock music [4]. These gender differences extend to emotional arousal, with females more likely to express emotions and experience depression or anxiety in response to external stimuli [5]. Such differences can also influence emotional arousal levels and attentional distraction.

Recent research by Xu and colleagues [26] used fMRI scanning to explore sex differences in negative emotion decision-making dynamics. Their findings revealed that girls exhibited less evidence accumulation at a faster pace with a lower decision threshold than boys when recognizing negative emotions in others. This was attributed to differences in amygdala-prefrontal systems in the brain indicating that females may possess a higher social awareness in emotional response. These findings highlight the significance of gender as a variable in studying emotion-related behaviors, such as decision-making.

In summary, music can evoke emotions that influence decision-making with fast-tempo music leading to less caution. Additionally, lyrics can convey semantic information that can distract cognitive activities. Moreover, gender differences in music preferences and emotional arousal may also impact decision-making. However, the role of lyrics in decision-making under background music remains an area requiring further exploration, particularly from the perspective of lyrics as a linguistic element.

2.5 Hypotheses

The current study investigates the effects of background music with lyrics and without lyrics on human's decision-making: mental arithmetic tasks. It tests the background music's arousal-influence and interferential-influence on the cognitive activities, further to study the gender difference in cognitive

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processing between two conditions. It is predicted that there will be a main effect for music with lyrics and without lyrics also a music×gender interaction. The hypothesis for current study as follows:

Hypothesis 1a. Background music types (with lyrics and without lyrics) has significant positive/negative effect on decision-making accuracy.

Hypothesis 1b. Background music types (with lyrics and without lyrics) has main effect on decision-making speed.

Hypothesis 2. Background music with lyrics will evoke emotion arousal level significantly different from background music without lyrics.

Hypothesis 3a. Background music and gender have interactive effect on decision-making accuracy.

Hypothesis 3b. Background music and gender have interactive effect on decision-making speed.

3. Method

A priori power analyzed by GPower 3.1 recommended the sufficient sample size to study a medium effect size with a power of .80 and an alpha of .05, indicating each group sample size was 64 for T-test, total sample size was 73 for Two-way ANOVA.

3.1 Participants

Two hundred and six Chinese adult participants were recruited to take the online questionnaire on mental arithmetic task and the Positive and Negative Affect Schedule (PANAS) [25]. There were twenty participants quitted the task, ten participants didn't finish the PANAS scale, by screening out those incomplete questionnaires, our study selected one hundred and seventy-six participants' answer sheets into the formal dataset of the current study, all the participants spoke Mandarin as their first language and their education level were not lower than the bachelor degree, including some were current college and university students.

3.1.1 Gender

One hundred and seventy-six participants were made up 88 males and 88 females who's age around 18-56 years (M=24.56 years, SD=6.98 years).

3.1.2 Groups

The study was designed into two background music condition groups: one is background music without lyrics, and the other is background music with lyrics. Forty-four male participants in group 1 (music without lyrics) aged 18-56 years, (M=25.89 years, SD=8.13 years), forty-four female participants in group 1 (music without lyrics) aged 18-42 years, (M=24.45 years, SD=6.29 years), forty-four males participants in group 2 (music with lyrics) aged 18-37 years, (M=22.45 years, SD=4.37 years), forty-four females participants in group 2 (music with lyrics) aged 18-39 years, (M=24.45 years, SD=6.69 years).

3.2 Materials

The experiment was carried out online by the Wenjuanxing website, the first part of the 83-item-long mental arithmetic questions of the questionnaire would be showed in Appendix A, the Positive and Negative Affect, moreover, the elements of the questionnaire have been interpreted below:

3.2.1 Music

The background music was using a Chinese pop song named "In this world there are crowds of people", which is familiar with Chinese adults nowadays in Mandarin language that set into two tracks, both of two music tracks were at the same tempo (bpm=72), same mode (B Flat Major), the only difference between two tracks was that one was sang by vocal with lyrics in Mandarin, the other was melody played by music instrument. Participants were asked to listen to music tracks at a constant level of intensity between 60 and 75 dB.

3.2.2 Task

The mental arithmetic task was made up of 83 questions selected from Chengdu elementary school second grade mental arithmetic test, mixed of addition, subtraction, multiplication and division, for

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example: 6×6-3= ___(1), 8×5+45=___(2), 8×2+14=___(3), etc., the task was designed to be not too easy nor too difficult, thus occupied participants' cognitive processing load not too low nor not too high, aimed to test the background music distracting effect.

3.2.3 Gender

Participants were asked to apply their gender information in the beginning question of the questionnaire, and then randomly divided into two groups; the number of males and females were equal in each treatment.

3.2.4 Emotion arousal

A great deal of studies regarded the Positive and Negative Affect Schedule (PANAS) was an efficient measure way to evaluate the emotional impact of music, it contained 20 items: 10 items referred to Positive emotional affects and 10 items referred to negative emotional affects, the answer of every item was graded from 1 to 5, the emotional arousal level was recorded by the total amount of items' scores. Regrading for its function, PANAS was administered in Chinese version in the final part of the questionnaire, which check the participants emotional arousal level.

3.3 Procedure

The online experiment was divided into three sessions; one was completing participants' basic information, including informed consent, gender, age, and education level. Then was completing 83 mental arithmetic questions in limited time:285 seconds. Last was completing 20 items of PANAS scale and 1 liking degree question of the background music.

Participants took part in the experiment individually through Wenjuanxing website link or QR code. After finishing the first part, participants would be selected to group 1 (background music without lyrics) or group 2(background music with lyrics) randomly, background music without lyrics would be played automatically once participants chose the "A" or "B" option. In the screen, it hinted participants began to solve the mental arithmetic problems in 285 seconds, thereby, participants were listening to the music and answering the problems synchronously. When the background stopped, the mental arithmetic task would be closed at the same time. The experimental answered in form of gap filling, which engaged participants make decision and mental processing quickly and as accurately as possible.

After that, the question "How do you like the background music just played before?" would show in front of the participants, after answering it, participants were asked to complete PANAS scale.

In short, the number of participants answered to the mental arithmetical questions was recorded and in percentage with the total amount of 83 question as the decision-making speed. The number of correct mental arithmetical questions in percentage with the answered questions' amount as the decision-making accuracy. The speed and the accuracy were the main dependent variables for data analysis.

3.4 Data Analysis

Descriptive statistics, for instance the mean (M), standard deviation (SD), standard error (SE), and 95% confidential intervals (CI) with lower limits and upper limits, were calculated for the total sample.

One-way ANOVA was used to examin the task speed between male and female within music types.

T-test between-subjects of two independent sample means was manipulated in the experiment, for instant, female's mental arithmetical task speed of music types, which had two levels: without lyrics vs. with lyrics.

The associations between mental arithmetical and PANAS scores, task speed and gender were explained by Spearman's correlation coefficient, to check out whether there was significant correlation between them.

Two-way ANOVA was used to examine main effect and interaction effect for each variable, such as music types × gender, music types × task speed, gender × task speed, gender ×emotion arousal, positive emotion arousal × task speed, negative emotion arousal ×task speed. The effect size was measure by partial eta-squared (η_p^2), interpretating the ratio of variance explained in the dependent variable by a predictor in the ANOVA model. The Tukey's honest significant difference test was performed to examine post hot differences between mean scores of each situation and group.

Nonparametric test was used to perform the difference of accuracy between two independent samples,

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e.g., task accuracy × two levels in gender: male vs. female, task accuracy ×two conditions in music types: without lyrics vs. with lyrics, which are examined by the Mann-Whitney significant difference test.

4. Results

Aiming to test the hypotheses, the analytic strategy of current study data was to first explored by examining at the distribution scores between the variables within the total sample (N=176), finding that in the mental arithmetic task, the speed rate obeyed normal distribution, which could be further analyzed by appropriate variance between background types, gender and emotion factor, whereas, the accuracy rate and emotion arousal scores did not showed normal distribution that they had to be analyzed by Nonparametric Test.

Correlation matrix (see Table 1) shows that there is a significant positive correlation, Spearman's coefficient r (174) = .268, p<.001, among the participants of Chinese adults between the Speed and Accuracy of the mental arithmetical task.

The means for all participants, involving male and female participants' performance in arithmetical task and PANAS scores are presented in Table 2. Based on the normality distribution, the mean speed (M=49.66, SD=14.12) of the background music with lyrics is less than without lyrics group (M=43.78, SD=18.08), moreover, male participants' mean speed ($M_{\text{without lyrics}}$=50.27, SD=16.41, $M_{\text{with lyrics}}$=46.22, SD=20.01) is great than females' ($M_{\text{without lyrics}}$=49.04, SD=11.55, $M_{\text{with lyrics}}$=41.35, SD=15.76) in both two treatments, generally speaking that without lyrics' group performance better than the lyrics one, man's mental arithmetical speed is faster than women's not only without lyrics but also with lyrics, which will continue to be demonstrated by T-test and the ANOVA to check the significance, main effect and interaction effect.

On the contrary, the means of accuracy rate for all participants, men and women was higher in the lyrics condition than without lyrics. Furthermore, the mean of positive emotion scores is elicited greater than the negative emotion in the lyrics condition than without lyrics under the background music, and that, in gender, female's emotion arousal shows higher than male in the lyrics condition rather than melody condition. Rank sum test and non-parametric test with Mann-Whitney U will analyze the variance of data in SPSS system.

Table 1: Correlation between Measures of Mental Arithmetical and PANAS Scores for All Participants.

Measure	Age	Educated degree	Speed	Accuracy	Positive emotion	Negative emotion	Gender	Music type	Liking degree
Speed	.030	.118		.268***	-.067	-.113	-.078	-.198**	.025
Accuracy	-.088	.061	.268***		-.071	-.041	-.118	.107	-.064
Positive-emotion	-.057	-.174**	-.067	-.071			-.079	.070	.300***
Negative-emotion	-.147	-.067	-.113	-.041			.034	.128	-.196**

Note. *p < .05, **p < .01, ***p < .001

Table 2: The Mean Speed Rate, Accuracy Rate and PANAS Scores for the Mental Arithmetical Task Under Background Music (with Lyrics and without Lyrics) for All Participants, Male Participants, and Female Participants.

Condition	Speed		Accuracy		Positive-emotion		Negative-emotion	
	M	SD	M	SD	M	SD	M	SD
All Participants								
Without Lyrics	49.66	14.12	92.75	5.34	23.15	9.80	15.88	6.62
With Lyrics	43.78	18.08	93.90	5.35	24.18	8.70	17.39	7.30
Male Participants								
Without Lyrics	50.27	16.41	92.97	5.66	24.20	10.32	16.52	7.11
With Lyrics	46.22	20.01	94.72	5.03	24.89	9.83	16.89	7.60
Female Participants								
Without Lyrics	49.04	11.55	92.52	5.05	22.09	9.24	15.23	6.11
With Lyrics	41.35	15.76	93.09	5.58	23.48	7.43	17.89	7.05

The following stratagem of analyzing consists of three parts. The first part examines the main and

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interactive effects of music types and gender types on the decision-making performance of speed, the main dependent variable. There is a significant main effect for music types in two gender, F (1, 172) =5.773, p<.05, η_p^2=.032 (see Figure 1). However, the interactive effect is marginally significant, F (1, 172) = .555, p=.475, η_p^2=.003. This result supports H1b but at the meanwhile rejects H3b that interpreting lyrics along with background music can affect the speed of human decision-making significantly rather than melody between male and female, the decision-making speed under background music lyrics are slower than without lyrics group, F (1, 86) =4.96, p=.027, η_p^2=.028 (see Table 3).

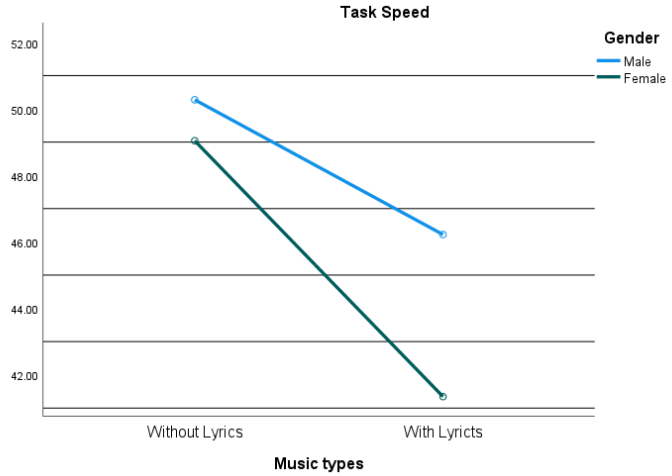

Figure 1: The Relationship between Music Types of Background Music and Task Speed.

Table 3: ANOVA Results between Music Types and Gender on Task Speed.

	Without Lyrics	With Lyrics	Music Types Main effect			Gender Main effect			Music*Gender Interactive effect		
	$\bar{X}$±S	$\bar{X}$±S	F	*P*	η_p^2	F	*P*	η_p^2	F	*P*	η_p^2
Male	50.27±2.44	46.22±2.44	5.77	.017	.032	1.56	.213	.009	.56	.46	.003
Female	49.04±2.44	41.35±2.44									

Note. *p<.05, **p<.01, ***p<.001

Based on the main effect of the music types, this current study explores decision-making speed on gender difference in two music type's treatments by using Generalized Linear Models, pairwise comparisons of marginal means between male and female participants' speed from background music without lyrics to with lyrics, female show significant difference in two conditions, implied that female's decision-making speed is affected by background music than male (see Table 4). Therefore, the speed of females in two conditions was further studied by T-test (see Table 5); female was influenced by background music more profoundly, and the speed in the lyrics condition was a significant difference from without lyrics one, much slower.

Table 4: One Way ANOVA of Task Speed between Male and Female within Music Types.

	Music Types		
	F	*P*	η_p^2
Male	1.374	.243	.008
Female	4.96	.027	.028

Note. *p<.05, **p<.01, ***p<.001

Table 5: T-test of Female's Mental Arithmetical Task Speed Difference Comparison in Two Background Music Treatments.

Treatments	$\bar{X}$±S	t	*p*	Difference 95% CI
Background music without lyrics	49.04±11.55	2.61	.011	1.839~13.55
Background music with lyrics	41.35±15.76			

Note. *p<.05, **p<.01, ***p<.001

The second part is analyzing the main and interactive effects of music types and gender types on the

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decision-making performance of accuracy (see Table 6), the main dependent variable. The result rejected the H1a and H3a that task accuracy is not statistical significance through Nonparametric tests and Mann-Whitney Test under music types (Z=-1.42, p=.16) and gender (Z=-1.56, p=.12), neither main effect nor interactive effect on decision-making accuracy rate between background music (without lyrics and with lyrics) and gender types.

The third part looks at the positive emotion and negative emotion scores' percentiles difference between two types of background music, to analyze whether slow music tempo along with sad lyrics will evoke negative moon significantly than melody. Because the object of the study was Chinese adults, the PANAS was adapted from Watson by Clark and Tellegen [25], translated into Chinese version for the current study. Positive affect score was accounting the scores by items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19, and negative affect score was summing by items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20. The reliability statistics of this Chinese version showed that Cronbach's Alpha is .90, the factor analysis showed that p<.001 and KMO was .898, indicating this scale earned high reliability and validity.

Table 6: Nonparametric Tests and Mann-Whitney Test on Accuracy Rate across Music Types and Gender.

	N	Percentiles			Statistics Z	*p*
		25th	50th (Median)	70th		
Music Types	176	90.00	94.59	97.20	-1.42	.16
Gender	176	90.00	94.59	97.20	-1.56	.12

Note. *p<.05, **p<.01, ***p<.001

Table 7: Mann-Whitney Test and Nonparametric Tests on Positive emotion across Music Types and Gender.

	N	Percentiles		Statistics Z	*p*
		50th (Median)	70th		
Music Types	176	23.00	30.00	-.93	.35
Gender	176	23.00	30.00	-1.03	.30

Note. *p<.05, **p<.01, ***p<.001

Table 8: Mann-Whitney Test and Nonparametric Tests on Negative emotion across Music Types and Gender.

	N	Percentiles		Statistics Z	*p*
		50th (Median)	70th		
Music Types	176	14.00	21.00	-1.70	.09
Gender	176	14.00	21.00	-.46	.65

Note. *p<.05, **p<.01, ***p<.001

Based on the PANAS scores does not obey the normality, emotional scores need to be examined by Nonparametric tests and Mann-Whitney Test (see Table 7, Table 8), displaying negative emotion underlying background music with sad lyrics (Z=-1.70, p=.09) is not significant difference from melody, nor does positive emotion (Z=-.93, p=.354), which rejects H2, demonstrating there is no significant difference between background music with lyrics nor melody when they evoke individual emotion. In addition, further in gender condition, positive emotion (Z=-1.03, p=.30) and negative emotion are not significant elicited by background music (Z=-4.55, p=.65).

To sum up of the results, the analysis of the current experiment data supports the H1b that background music has the main effect on the speed of human decision-making task, participants process slower when they listen to music with lyrics than music without lyrics, the task speed difference between two music types is significant, particularly for females' is sufficiently large than male. Whereas, the results interpreting inconsistent with the other hypotheses that reject H1a, H2, H3b, background music without lyrics and with lyrics show no main effect nor interactive effect on decision-making (mental arithmetical task) with gender, even it is not sufficiently different of evoking emotion arousal level from background music without lyrics to with lyrics.

5. Discussion

This study employed an online between-subjects design, incorporating an 83-item mental arithmetic task and the PANAS emotion arousal scale for each participant. Its primary objective was to investigate the impact of background music on decision-making, speed, accuracy, and emotion arousal, with music

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types (with lyrics and without lyrics) and gender as the main independent variables. Statistical analyses were used to test hypotheses concerning the effect of background music with lyrics on participants, specifically whether it led to slower and less cautious cognitive activities and elicited stronger emotions compared to background music without lyrics.

5.1 Background music with lyrics and the accuracy of decision-making

Previous research has suggested that background music can decrease caution and accuracy in decision-making when compared to silence [20]. Given that lyrics can interfere with cognitive activities through phonemic and semantic processing, it was hypothesized that the presence of lyrics would have a more significant impact on decision-making accuracy. However, this study did not find a significant main effect or interactive effect of lyrics and lyrics×gender, indicating no significant difference in accuracy between the two treatments. This suggests that semantic and melodic processing do not differ significantly from each other, and individuals perform equally well under conditions with or without lyrics. Thus, lyrics do not appear to primarily influence decision-making accuracy for both men and women when working with background music.

5.2 Background music with lyrics and the speed of decision-making

This study utilized a slow-tempo (bpm=72) pop song as the background music, with the only variation between treatments being the presence or absence of lyrics. Slow tempo has previously been associated with a stronger effect on slowing down decision-making evidence threshold compared to silence [20]. The study focused on mental arithmetic tasks, which require individuals to be cautious and avoid errors. This engages individuals to be more cautious and operated at a slower pace, a phenomenon known as prevention focus [10]. The results indicated that the background music with lyrics condition led to a slower speed in decision-making compared to the condition without lyrics. This consistent and significant effect aligns with previous research on reaction time and supports the notion that background music with lyrics can slow down decision-making speed to a greater extent than music without lyrics.

5.3 Gender difference

While prior studies have explored the impact of personality such as introversion and extraversion, on decision-making performance under background music [8], this study aimed to address the gap in gender differences. It explored whether there were significant differences between men and women in decision-making performance when exposed to background music with or without lyrics. The participants were Chinese adults with Mandarin as their first language and an educational degree above senior school level, helping control for individual differences. The results highlighted a gender difference in decision-making speed, with females performing significantly slower than males in the background music with lyrics condition. Women's attention appeared to be more influenced by background music with lyrics, causing a delay in their work pace. In contrast, male participants did not show a significant difference in the two conditions when completing the task under background music. However, gender differences require further research, as gender differences can encompass various dimensions, including biological, social and competence factors.

5.4 Positive and negative emotional arousal

Prior research has demonstrated that music can robustly influence incidental emotions, impacting decision-making and other mental activities. The study adopted a slow-tempo pop song with sad lyrics, to evoke stronger negative than positive emotions. However, the results did not support this hypothesis, as there was no significant difference in negative emotion between the two conditions, even when using a familiar pop song with sad lyrics. This finding contrasts with previous conclusions suggesting that lyrics have a more significant impact on mood arousal than melody alone [23]. The effect of lyrics combined with melody on evoking specific emotions may depend on individual subjective experiences and requires further exploration.

5.5 Applications

The study has implications for individuals who listen to music while working, studying, or engaging in various mental activities. It suggests that background music with lyrics can significantly slow down decision-making speed, especially for women. Therefore, individuals who need to complete tasks quickly

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or within time constraints should avoid listening to background music with lyrics. Conversely, background music, whether with or without lyrics, appears to need more task accuracy. This suggests that individuals can listen to background music without concern for their decision-making accuracy. For example, drivers may prefer to listen to soft, non-lyrical music to maintain stable driving [11]. Additionally, slow-tempo background music with lyrics was found to significantly impact on emotional arousal, potentially helping individuals relax when making decisions under stress.

5.6 Limitations and further research

While this research sheds light on the influence of lyrics in background music on decision-making activities, it has certain limitations. Firstly, the between-subjects design may introduce individual differences that increase variability in the data. Future research could adopt a within-subjects repeated-measures design to examine the effects of background music with lyrics, without lyrics, and silence across different age groups with similar psychological development stages. Secondly, the online nature of the experiment, conducted in questionnaires comprising mental arithmetic questions and the PANAS scale, may have introduced unexpected factors such as environmental noise. Future studies could consider conducting experiments in controlled environments to mitigate such factors. Lastly, this study found no significant difference in negative emotion arousal between conditions, further research is needed to explore the effects of lyrics combined with melody on other mental activities and emotional responses, considering individual subjective experiences.

5.7 Conclusions

The results indicate that gender types and background music with lyrics appear to have no significant difference from the melody on the accuracy rate in mental arithmetical tasks nor emotional arousal. Inversely, the speed of the decision-making task shows significant difference between the two music type treatments; it pointed out that music types have a main effect on the decision-making speed; participants perform slower in the music with lyrics than without lyrics. However, there is marginally significant interaction by background music types and gender in decision-making speed, when further study on gender, it appears that female group shows significant difference in two treatments, women in background music with lyrics performance observably slower than the melody condition in particular cognitive process.

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Appendix A

The mental arithmetic task, made up of 83-itemt-long questions selecting from Chengdu elementary school second grade mental arithmetic test.

1. 6×6-3=	19. 8×3+89=	37. 75+5×3=	55. 29-1×2=	73. 4+8×6=
2. 8×5+45=	20. 56+71-23=	38. 74-8×7=	56. 73-10÷10=	74. 2×5×3=
3. 3×4×9=	21. 57-13-42=	39. 52+6×0=	57. 40÷4-5=	75. 72÷8÷3=
4. 1×27÷3=	22. 7+0+94=	40. 45÷9-4=	58. 30÷10+65=	76. 81-5×2=
5. 8×2+14=	23. 8÷8-0=	41. 12÷2×6=	59. 8×5-14=	77. 3×4-9=
6. 9×1×4=	24. 9×0×8=	42. 5+12÷3=	60. 100-2×1=	78. 30÷3+42=
7. 42÷6×2=	25. 18-1×5=	43. 61-50-7=	61. 23-0-18=	79. 33+2×4=
8. 9×9-61=	26. 38-7+69=	44. 8+40+18=	62. 4+5×6=	80. 50÷5+72=
9. 70-3+13=	27. 12÷4×2=	45. 50-1÷1=	63. 15-1-7=	81. 36÷6+26=
10. 47-11-21=	28. 38+80÷8=	46. 4×5-19=	64. 6÷1×4=	82. 10÷2+63=
11. 432÷8÷9=	29. 28-2×8=	47.65+7×3=	65. 11+86-1=	83. 10+40-9=
12. 30÷5+58=	30. 79-73-4=	48. 78-81÷9=	66. 7+20+7=	
13. 108÷3÷4=	31. 18-63÷7=	49. 22+35÷5=	67. 22-3×7=	
14. 8×2×7=	32.9×2-10=	50. 9÷1+9=	68. 24÷4-4=	
15. 5÷1×5=	33.7×0+31=	51. 4÷1×9=	69. 28+5×1=	
16. 72÷9-1=	34. 12÷4÷3=	52. 20÷10+18=	70. 46-3+20=	
17. 87-7×7=	35. 72÷8-1=	53. 24÷8-1=	71. 7×5×8=	
18. 48÷8-0=	36.53-37-4=	54. 16÷4×3=	72. 3×70÷10=	