Effect of music tempo on reaction time during study: an investigation on university students

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Abstract. Several studies have been conducted to reveal the impact of specific music on cognitive functions. However, the effect of music tempo of human intelligence still holds great potential for further research. The purpose of this research is to examine the influence of specific music tempos (adagietto, moderato, and assai) on the concentration levels of students at Diponegoro University during the study. This experiment uses the stroop task paradigm in a design experiment within the subject from August to September 2023. The study involved a total of 42 participants from the Industrial Engineering Department with four treatment conditions (no distraction, adagietto tempo, moderato tempo, and assai tempo). Data collection was carried out for each treatment at a 24-hour interval. Then, the result data for the three variables (accuracy, reaction time, & stroop effect) are analyzed. The results of the statistical analysis indicate a significant increase in reaction time with $p < 0.05$ ($0.004 < 0.05$). The post hoc test indicates a significant difference between non-music treatment and assai tempo with $p < 0.05$ ($0.008 < 0.05$). The tempo assai treatment resulted in higher reaction times compared to the no music treatment, with values of 772.826 ms and 665.489 ms, respectively.

1 Introduction

Music has been an important part of human life for a long time. Even during the Covid-19 pandemic, listening to music has become an increasingly frequent activity [1]. Students are no exception; they often do assignments or study while listening to music [2]. This tendency is generally because music is expected to create a pleasant learning environment [3].

Music is defined as a combination of sounds that form a beautiful rhythm. The process of

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creating music entails arranging sounds and tones sequentially and merging them to form a cohesive musical piece. The beautiful strains of music make many people listen to music to reduce negative emotions, regulate mood, and relieve daily stress [4].

Research on the effect of music on humans has been done before [5]. The effect of music on human cognition is one of the most frequently studied aspects. The effects are also very diverse. Previous research revealed that participants needed more effort to complete a task while listening to music [6]. While in another study, turning off music while performing an activity has a negative effect on participants' performance. According to conducted studies, music is said to have the ability to stimulate human brain waves that can improve thinking, reading, memory, concentration, vocabulary and create a positive mental state [7].

In one experiment conducted on participants with an age range of 19-28 years, it was shown that listening to classical/jazz music can have a better effect on increasing attention compared to fast-tempo music [8]. Research on the effect of other music tempos shows that slow tempo produces negative emotions in listeners [8]. Previous research has also shown that mid-tempo music leads to a decrease in the amount of exertion performed [9]. Of the many studies on how music affects human concentration levels, there has been limited research conducted to compare the impact of different music tempos and identify which has the most positive effect on human cognition, especially concentration levels including reaction time. Hence, this study seeks to address the knowledge gap and enhance comprehension regarding the influence of music tempo on students' reaction time.

In making the research more specific, the type of treatment is done with musical accompaniment which is further categorized according to the tempo of the music. Tempo is divided into three types: slow, medium, and fast. There are several terms in tempo such as (largo, adagio, adagietto, andante, maestoso, moderato, allegro, etc) [10]. In this research, the three musical tempos chosen are adagietto, moderato, and assai. These three tempos were chosen because they represent a wide range in terms of musical tempo and the emotional impact they can produce. They are also the most common tempos used in songs today. The three tempos, namely slow (adagietto), moderate (moderatto), and fast (assai), were tested on the concentration level of class of 2021 Industrial Engineering Students using the stroop test. This study measures how music affects concentration levels in terms of three variables: accuracy of answers, reaction time, and stroop effect when given a musical stimulus from three different tempos. Data were collected and statistically analyzed to identify significant differences in concentration between treatments. The results of this study can be useful in an educational context, with implications for the use of music as a medium to improve student concentration and productivity in the context of classroom learning or work environments.

2 Methods

2.1 Time, location, & subjects

This research began with data collection, which was carried out from August to September 2023. The data collection location is in the Multimedia Room of the Industrial Engineering Campus of Diponegoro University with the layout shown in Figure 1. The participants were 42 active students in Industrial Engineering Diponegoro University Class of 2021 with an age range of 19-21 years.

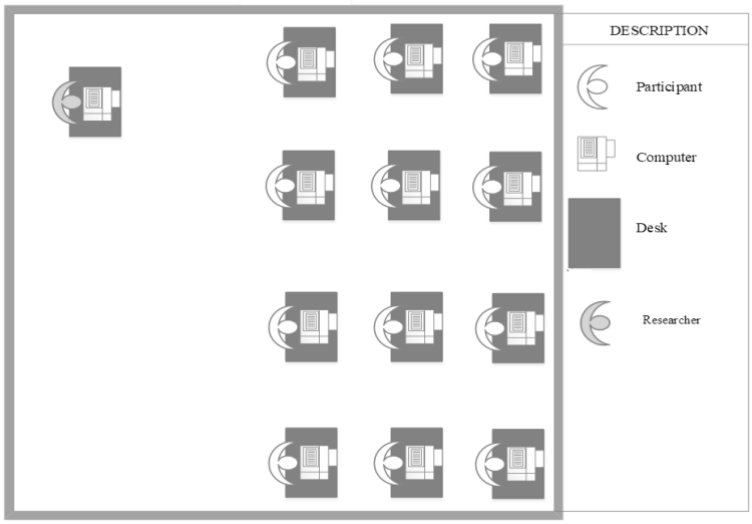

Fig 1. Multi media room layout.

2.2 Data collection procedure

Each participant participated in four treatments that were conducted over several days. Each treatment was spaced 24 hours apart to avoid learning effects from the previous treatment. Before the day of data collection, participants were provided information and training on the use of the stroop test. Participants are expected to be familiar with and utilize the Stroop test to ensure clarity during data collection. Furthermore, on the day of data collection, the series of activities are divided into several stages.

At the initial stage, participants will receive an explanation of the flow and mechanism of data collection that will be carried out. Furthermore, participants are asked to calm themselves first for 20 minutes according to research showing that cortisol that causes stress will be reduced for 20 minutes after the first occurrence of stress [11]. The activity continued with participants doing the stroop test through the psytoolkit.org website. Participants conducted the stroop test with 2 types of research treatments, namely without musical accompaniment and with musical accompaniment.

In conducting the stroop test with musical accompaniment, there are three types of music tempo that will be played, namely, adagietto tempo, moderato tempo, and assai tempo. Each music will be played randomly so that each participant will listen to the music in a different order. Each treatment is performed on a different day. The music that will be played is I'm Yours - Mary Lou Stephens (Slow Tempo); *Shape of You* (Medium Tempo); Wstr-Crisis (Fast Tempo). After that, the researcher recapitulates the data on the results of the stroop test that the participants have performed. The recapitulated data included the number of accuracy, reaction time, and stroop effect obtained from the test. The flow data of data collection shown in Figure 2 & Figure 3.

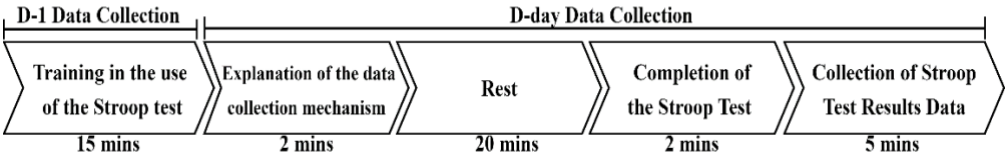

Figure 2. Flow of data collection without music

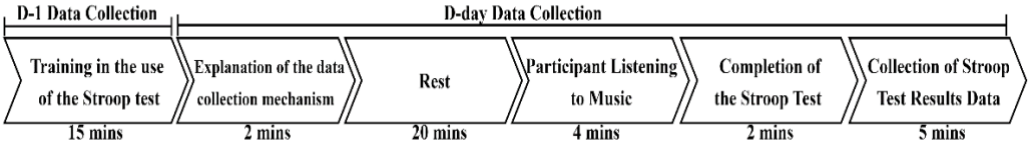

Figure 3. Flow of data collection with music

In this study, participants will receive brief instructions about the *stroop test* along with the conditions that have been set. The following are the conditions that have been set before conducting this research.

1. The participants were in good health (no unwell symptoms such as dizziness, nausea, weakness, etc).
2. The participants had breakfast before taking the test.
3. Participants wear assistive devices such as headphones or headsets.
4. The participants had slept for at least 6 hours prior to the stroop test.
5. Participants did not consume caffeine such as coffee or tea for 5 hours before performing the stroop test.
6. Data collection was carried out in a quiet place, namely the Multimedia Room of the Industrial Engineering Building, Diponegoro University.
7. Data collection was carried out with the help of the psytoolkit.org *website* (www.psytoolkit.org/experiment-library/stroop.html) with the type of Stroop Task experiment.
8. The data collection time span was from 09.00-13.00 during the time period of August to September 2023.

2.3 Stroop test

The stroop test is a cognitive assessment related to reaction time, executive function, attention, information processing speed, cognitive flexibility, cognitive inteference, and *working memory*. The Stroop test typically involves words associated with color names and is administered in two conditions: congruent and incongruent. Congruent appears when the attribute and stimulus match; for example, the word "red" displays the colour of the word red. Incongruent appears when both, the attribute and the stimulus do not match, e.g. the word "red" is displayed in a different color [12].

Various adaptations of Stroop tests have surfaced and been employed across multiple fields, including social psychology, the cognitive-motor dual task paradigm, mental development, and sentence comprehension studies [13] . In this study, a stroop test based on the psytoolkit.org website was used with the stroop task experiment, where participants were asked to mention the color of the word without paying attention to the word written as shown in Figure 4. The test results of the stroop task that will be studied are accuracy, reaction time, and stroop effect. There are four colors used in this stroop test, namely red, green, blue, and yellow with congruent and incongruent conditions randomized [14].

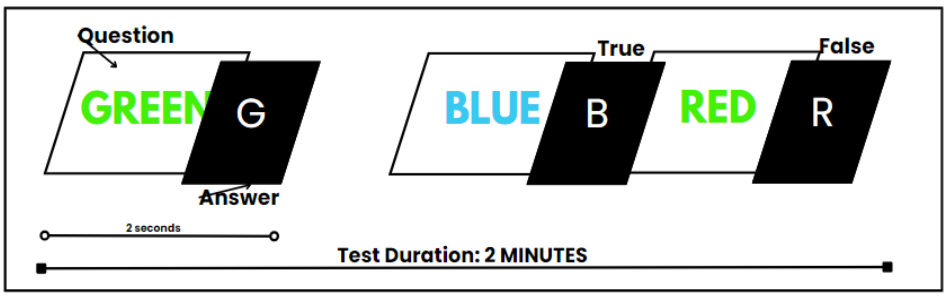

Figure 4. Stroop test schematic

2.4 Statistical analysis

After collecting a sample of 42 participants, the examiner processed the data from the participants' stroop test results using the normality test, homogeneity of variance test, ANOVA test, and Post Hoc test. The purpose of the Normality Test is to examine whether the confounding and residual variables in the regression model follow a normal distribution, thereby assessing whether the data exhibit normal distribution characteristics. The simplest normality test is to make a frequency distribution graph over the existing scores [15]. Furthermore, the homogeneity test is a statistical procedure designed to demonstrate that multiple groups of data samples are drawn from populations with equal variance [16]. ANOVA is one of the parametric tests that serves to distinguish the average values of more than two groups of data by comparing their variances [17]. In this study, the ANOVA test was used to test reaction time, accuracy, and stroop effect.

3 Results

3.1 Recapitulation of measurement output

In this study, data collection involved a total of 42 samples. Based on the data collection that has been done with the stroop test, several output results are obtained, namely the value of accuracy, reaction time, and stroop effect with 4 different treatments. The following is a recapitulation of the results of measuring accuracy, reaction time, and stroop effect.

Table 1. Recapitulation of data collection results

No.	Variables	Treatment	Average	Std Deviation
1.	Accuracy	1	38,33	2,11
		2	38,40	1,80
		3	38,45	1,66
		4	38,36	2,38
2.	Reaction Time (ms)	1	772,83	171,28
		2	748,92	159,30
		3	691,78	145,02
		4	665,49	125,28
3.	Stroop Effect (ms)	1	74,57	114,01
		2	115,36	87,15
		3	79,19	78,47
		4	79,17	81,80

Description:

1 : No music distraction
2 : Slow tempo distraction
3 : Medium tempo distraction
4 : Fast tempo distraction

3.2 Data analysis

Data processing in this study involved several stages of statistical analysis. Data were processed using the ANOVA test (Analysis of Variance) test to test whether there are significant differences between groups of independent variables on several dependent variables. Next, we conducted a post hoc test to evaluate the differences between the groups in more detail, identifying which groups were different from each other.

After applying ANOVA and post hoc tests, a classical assumption test was performed as validation, namely the normality test to ensure that the data followed a normal distribution. As well as conducting a homogeneity of variance test to check whether the variances between groups of the dependent variable are comparable.

3.2.1 ANOVA test

The following is an analysis of variance for accuracy as shown in Table 2.

Table 2. Analysis of variance for accuracy

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	3	0,351	0,351	0,117	0,30	0,994
Error	164	677,500	677,500	4,131		
Total	167	677,851				

Based on the results of the accuracy variance analysis using Minitab, it is found that the *p-value* > 0.05 (0.994>0.05), so it can be concluded that the treatment carried out does not simultaneously affect the accuracy with a confidence interval of 95%. The following is an analysis of variance for reaction time as shown in Table 3.

Table 3. Analysis of variance for reaction time

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	3	310564	310564	103521	4,53	0,004
Error	164	3748911	3748911	22859		
Total	167	4059475				

Based on the results of the analysis of variance for the reaction time, using Minitab, the *p-value* <0.05 (0.004<0.05), so it can be concluded that the treatment carried out simultaneously affects the reaction time with a confidence interval of 95%. The following is an analysis of variance for the stroop effect as shown in Table 4.

Table 4. Analysis of variance for stroop effect

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	3	45399	45399	15133	1,81	0,147
Error	164	1371210	1371210	8361		
Total	167	1416609				

Based on the results of the analysis of variance for the stroop effect using Minitab, the results show that the *p-value* >0.05 (0.147>0.05), so it can be concluded that the treatment carried out does not simultaneously affect the stroop effect at a significance level of 0.05 with a confidence interval of 95%.

3.2.2 Post hoc test

The post hoc test is a statistical analysis used after conducting an analysis of variance test. The post hoc test is used to evaluate the significant differences between the treatment groups in the study. The following are the results of the post-hoc statistical testing on the accuracy variable using Minitab software as shown in Table 5.

Table 5. Post hoc test of accuracy

Difference in Treatment Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-value	Adjusted *p-value*
2 - 1	0,071	0,444	(-1,113; 1,256)	0,16	1,000
3 - 1	0,119	0,444	(-1,065; 1,304)	0,27	1,000
4 - 1	0,024	0,444	(-1,161; 1,208)	0,05	1,000
3 - 3	0,048	0,444	(-1,137; 1,232)	0,11	1,000
4 - 2	-0,048	0,444	(-1,232; 1,137)	-0,11	1,000
4 - 3	-0,095	0,444	(-1,280; 1,089)	-0,21	1,000

Based on the results of the post hoc test on the accuracy variable, the *p-value* >0.05, which means that there is no significant difference. The following are the results of the statistical test of the post hoc test on the reaction time variable using Minitab software, as shown in Table 6.

Table 6. Post hoc test reactions time

Difference in Treatment Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-value	Adjusted *p-value*
2 - 1	-23,9	33,0	(-112,0 ; 64,2)	-0,72	1,000
3 - 1	-81,0	33,0	(-169,2 ; 7,1)	-2,46	0,090
4 - 1	-107,3	33,0	(-195,4 ; -19,2)	-3,25	0,008*
3 - 3	-57,1	33,0	(-145,3 ; 31,0)	-1,73	0,511
4 - 2	-83,4	33,0	(-171,5 ; 4,7)	-2,53	0,074
4 - 3	-26,3	33,0	(-114,4 ; 61,8)	-0,80	1,000

**significant at p-value <0.05*

Based on the results of the post hoc test conducted, it was found that the *p-value* <0.05 was at the 4 - 1 treatment level, which means that in the 4 - 1 treatment there was a significant difference. The following are the results of statistical testing of the Post Hoc Test on the stroop effect variable using Minitab software as shown in Table 7.

Table 7. Post hoc stroop effect test

Difference in Treatment Levels	Difference of Means	SE of Difference	Simultaneous 95% CI	T-value	Adjusted *p-value*
2 - 1	40,8	22,0	(-11,0 ; 92,6)	2,04	0,176
3 - 1	4,6	22,0	(-47,2 ; 56,4)	0,23	0,996
4 - 1	4,6	22,0	(-47,2 ; 56,4)	0,23	0,996
3 - 2	-36,2	22,0	(-87,9 ; 15,6)	-1,81	0,271
4 - 2	-36,2	22,0	(-88,0 ; 15,6)	-1,81	0,271
4 - 3	-0,0	22,0	(-51,8 ; 51,8)	-0,00	1,000

Based on the results of the post hoc test on the stroop effect variable, the *p-value* >0.05, which means that there is no significant difference.

3.3 Validation test

The data validation test is an important step in data processing and statistical analysis that aims to ensure that the data used in research or analysis are truly reliable and accurate. The validation tests used in this study are the normality test and the homogeneity test.

3.3.1 Normality test

The normality test is used to determine whether the data observed or collected have a distribution that is close to a normal distribution.

- **Accuracy**

Based on the graph results and the *p-value* as shown in Figure 5, it can be seen that the data group has a *p-value* <0.010, which means that the accuracy data variables in this study are not normally distributed.

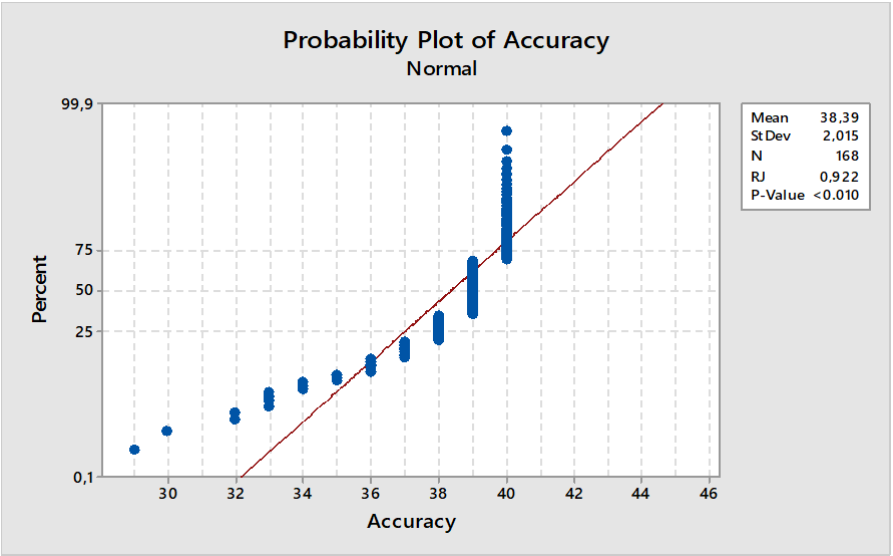

Figure 5. Graph of probability plot of accuracy

- **Reaction Time**

Based on the graph results and the *p-value* as shown in Figure 6, it can be seen that the data group has a *p-value* <0.010, which means that the variable reaction time data in this study are not normally distributed.

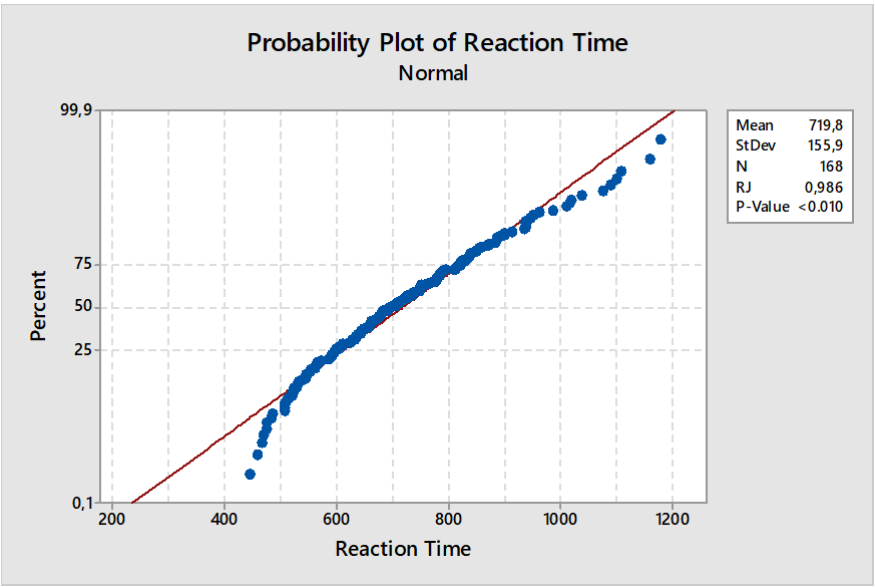

Figure 6. Graph of probability plot of reaction time

- **Stroop Effect**

Based on the graph and *p-value* results in the figure as shown in Figure 7, it can be seen that the data group has a *p-value* > 0.100, which means that the stroop effect data variable in this study is normally distributed.

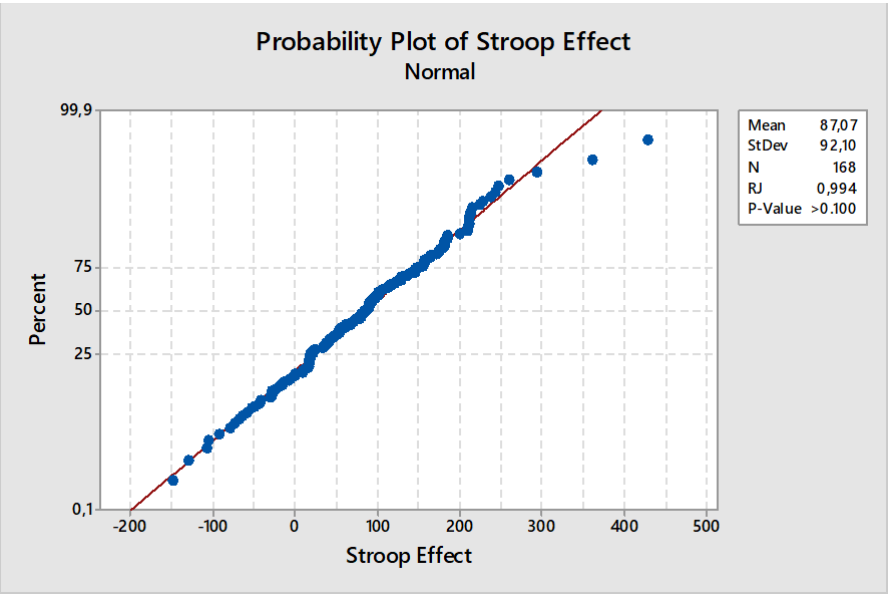

Figure 7. Graph of probability plot of stroop effect

3.3.2 Homogeneity Test

The homogeneity test is a statistical test used to determine whether the variability or dispersion of data between two or more groups or samples is the same or homogeneous. That is, knowing the uniformity or similarity of variability between groups.

- **Accuracy**

Based on the results of the graph and the *p-value* Levene's Test as shown in Figure 8. It can be seen that the data group has a *p-value* > 0.05, which is 0.772, which means that the variation of treatment data and accuracy variables is homogeneous.

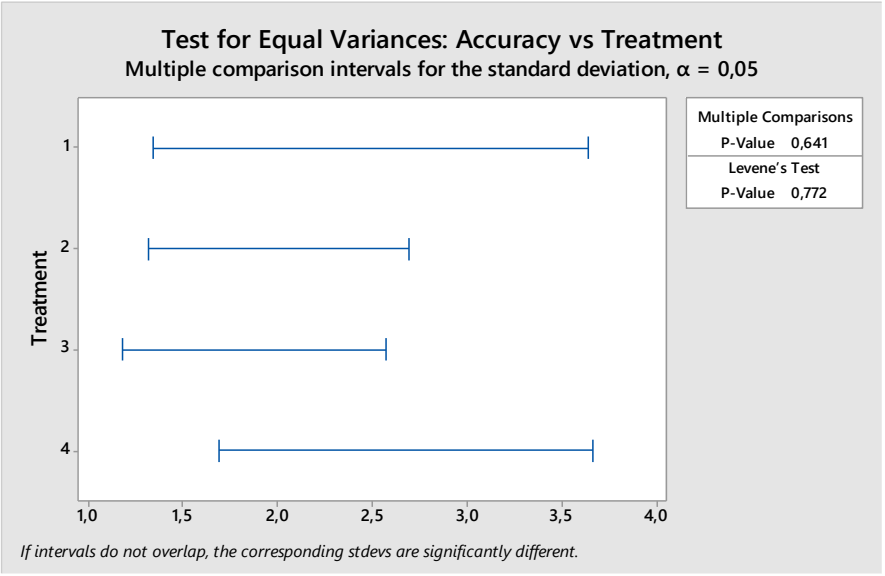

Figure 8. Test for equal variances of accuracy

- **Reaction Time**

Based on the results of the graph and the *p-value* Levene's Test as shown in Figure 9 it can be seen that the data group has a *p-value* > 0.05, which is 0.223, which means that the variation of treatment data and reaction time variables is homogeneous.

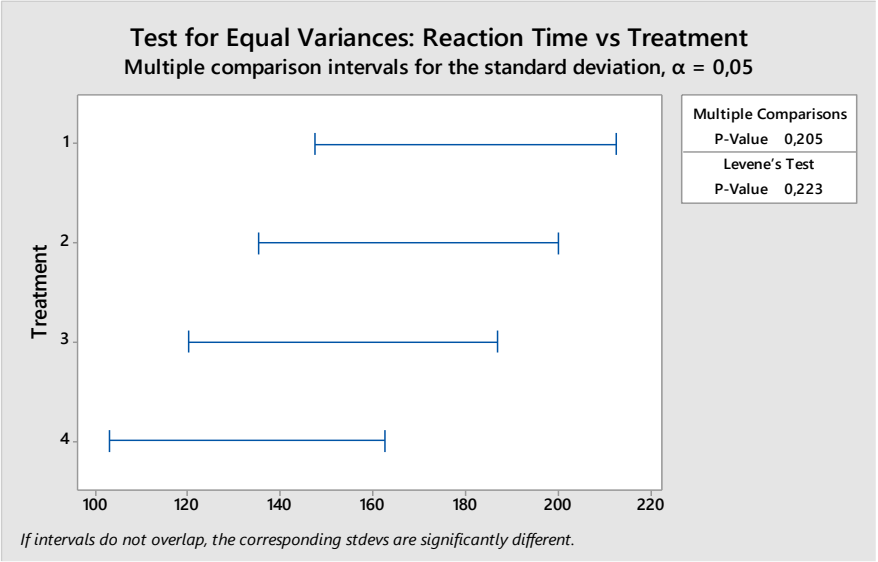

Figure 9. Test for equal variances of reaction time

- **Stroop Effect**

Based on the results of the graph and the *p-value* Levene's Test as shown in Figure 10, it can be seen that the data group has a *p-value* > 0.05, which is 0.061, which means that the variation of treatment data and the stroop effect variable is homogeneous.

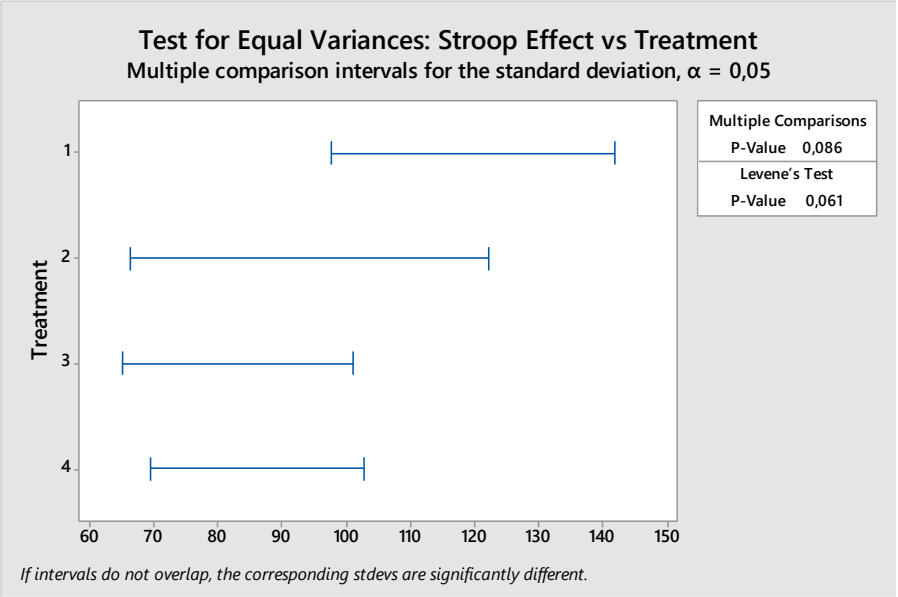

Figure 10. Test for equal variances of stroop effect

4 Discussion

Based on statistical tests that have been carried out using ANOVA on the accuracy variable, it is found that the treatment carried out has no significant effect (p >0.05 with p = 0.994). This means that there is no effect of the type of music tempo on accuracy in cognitive tests related to selective attention & speed processing. The results of this study contradict previous research which shows that slow tempo music increases attention significantly compared to fast tempo music and no music at all [18]. Similarly, a study showed that hiphop music that falls into the medium music tempo actually decreases the level of attention when performing comprehensive reading tasks compared to slow music tempo such as classical music [19]. The findings of both studies were evidenced by higher scores on cognitive tests on slow music tempo types. This may be due to the limitations of our study which includes participants from similar studies (class of 2021) with a narrow age range (19 - 21 years old), different participant characteristics, and different number of participants.

In the reaction time variable, it was found that the treatment carried out had a significant effect (p <0.05 with p =0.004). Then, we continued with the post hoc test using the Bonferroni method to see which differences were significant between the treatment groups. There was a significant effect for the treatment without music with a fast tempo (p < 0.05 with p = 0.008). This means that there is a significant effect on the reaction time of the type of fast music tempo. This finding is in line with previous research which shows that the type of fast tempo pop music produces shorter reaction times than the type of slow tempo pop music in cognitive performance tests [20]. In Figure 11., it is shown that there is a decrease in reaction time for each treatment tested where the faster music tempo sequentially produces shorter reaction times. In the stroop effect variable, it is shown that there is no significant difference between treatments (p <0.005 with p =0.147). This means that the stroop *effect is* not influenced by the type of music tempo.

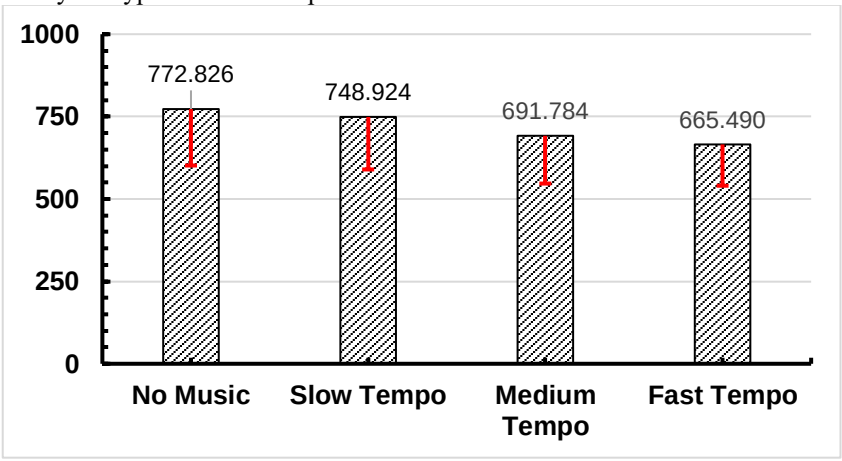

Figure 11. Comparison of reaction time of each treatment

According to the conducted research, it can be concluded that the type of music tempo, especially fast tempo music has a positive influence on reaction time in cognitive performance tests as a representation of student learning activities. This is not without reason, considering that music has an influence on a person's *mood*, whether it is sad, happy, or excited [21]. Fast tempo music is able to arouse the enthusiasm of the participant in doing the stroop task so that it affects the reaction time which becomes faster than if there is no music, music with slow tempo, or music with medium tempo. However, this study also has limitations, including the possibility of cases of misinterpretation of the participants

concerned. This may have affected their test performance differently compared to other participants. In addition, individual reactions to different types of music tempo may have different effects on each participant where an individual may be more sensitive or have a stronger "learning style" preference for auditory stimulisation than other participants so that the reaction time of that individual may be greatly affected compared to other participants.

5 Conclusion

According to the conducted research, there are several things that can be concluded, including that the reaction time of a person during learning activities can be measured through the stroop test which has output parameters, namely accuracy, reaction time, and stroop effect. The accuracy parameter measures the number of correct scores after doing the stroop test, the reaction time parameter measures the average of how long it takes participants to answer each stroop test question, while the stroop effect measures the average of how the stroop effect received by participants after completing the stroop test. The type of music tempo, especially fast tempo music has an influence on reaction time in cognitive performance tests as a representation of student learning. The fast music tempo has a significant effect. The higher the tempo of music, in this case the tempo of slow, medium, and fast music, gives a positive influence on the reaction time of a person's reaction time when cognitive performance tests are used, representing studying.

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