

Music and Memory

The Island Research Project - Statistics 101B

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Contents

Abstract	2
Introduction	2
Experiment	2
Participants	2
Design	3
Instruments	5
Procedure	6
Data Analysis	6
Data Structure	6
Statistics of sample	6
Exploratory Data Analysis (EDA)	8
Paired t-test	9
Analysis of Variance (ANOVA)	10
Multiple groups comparison	12
Model assumption checking	14
Conclusion	15
Discussion	15
References	16
Journal References	16
Publication References	16

Abstract

We have all heard about the saying that music can help improve one's memory. Based on the fact that we have access to different types of musical treatments and memory tests, the goal of this research project is to find whether there is an effect of music on islander's memoriation ability, and which type of music has the most significant improvement on human's memorization capability. The research is conducted using the open platform *The Island*¹.

Introduction

According to an annual report produced by the Administration for Community Living, about one in every seven Americans is over the age of 65 in 2017, and the proportion will swell to one in five by 2040. Old age is accompanied by declines in mental domains such as processing speed, reasoning, memory and executive functions (Ian J. Deary, 2009). As America along with the rest of the world enters an aging society, there is a growing interest in identifying factors that can alleviate age-associated cognitive decline.

It has been suggested by some researches (Cirigliano, 2013; Michael, David, Gerald, & Volker, 2014) that the temporal pattern structure in music can enhance cognition and memory retention. This effect appears to be especially significant for people with cognitive deterioration/impairment. Such theory has been put to practice by organizations such as MUSIC AND MEMORY, a non-profit that brings personalized music playlists to elders in nursing homes. They claim that "Music is the most 'fast-acting' non-drug approach to improving the lives of all persons with dementia, Parkinson's, depression and other behavioural challenges" (2017 Impact Report, pg 1).

Another interest of substantive researchers is the effect of different genre of music on memory and cognition. There is a considerable amount of publication dedicated to investigating the effect of Classical music on performance and memory retention. Rausher, Shaw and Ky (1993) found that listening to classical music improved intelligence and memory (the "Mozart Effect") and a British radio station specialised in western classical music was shown to help listeners relax and improve brain efficiency (Blanchard, 1979). Other studies compared different genres of music and concluded fast-paced music such as Rap and Heavy Metal may distract cognitive effects and lead to poorer performance (Dibben & Williamson, 2007; Smith & Morris, 1977).

Due to music's accessibility as well as its universal presence, our study is interested in testing whether there is theoretical support for the uses of music as a means for memory improvement. We propose that listening to music will lead to a statistically significant increase in the memory test score. For this study, we apply four genres of music (Country, Classical, Dance, Heavy Metal) as treatment variables and a control variable (No Music).

In this experiment, our goal is to:

- (1) test if music is a valid treatment for increasing memory performance;
- (2) find the best genre of music that leads to said improvement.

Experiment

Participants

We chose the virtual participants from the online resource the Island. We found that female who age 65 or older are most susceptible to cognitive impairment and are outperformed by men (in the same age group) in fields of visuospatial, verbal processing, semantic and episodic memory (Laws, K. R. 2016). Because memory

¹The Island: <http://island.maths.uq.edu.au>

retention differs in individual (M. Karl Healey 2014), and in time of the day (A. D. Baddeley, 2007), we use Latin Square to block by individual subject and time of the day. In order to increase power as well as our error degrees of freedom, we repeated this 5*5 Latin Square five times. This resulted in our necessary sample size of 25 participants. Moreover, studies have shown that cognitive impairment and dementia are predicted to increase proportionately more in developing regions, thus indicating a potential association between the region of residence and cognitive performance (WHO, 2013). We decide to hold this factor constant and choose participants from the Town Macondo, where the population of senior citizens is the largest. In order to obtain the 25 participants, we went to the 64 neighbourhoods of Macondo and request consent from female participants age 65 to 89.

Design

The design that we have chosen to use in this project is 5 x 5 Latin Square with five replicates.

Model:

$$y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \epsilon_{ijk}, \text{ where } i, j, k = 1, 2, 3, 4, 5$$

Time islander	9 am	12 pm	3 pm	6 pm	9 pm
Islander 1	A	B	C	D	E
Islander 2	E	A	B	C	D
Islander 3	D	E	A	B	C
Islander 4	C	D	E	A	B
Islander 5	B	C	D	E	A

Figure 1: Latin Square Design

Time Islander	9 am	12 pm	3 pm	6 pm	9 pm
Islander 6	E	A	B	C	D
Islander 7	D	E	A	B	C
Islander 8	C	D	E	A	B
Islander 9	B	C	D	E	A
Islander 10	A	B	C	D	E

Time Islander	9 am	12 pm	3 pm	6 pm	9 pm
Islander 11	D	E	A	B	C
Islander 12	C	D	E	A	B
Islander 13	B	C	D	E	A
Islander 14	A	B	C	D	E
Islander 15	E	A	B	C	D

Time Islander	9 am	12 pm	3 pm	6 pm	9 pm
Islander 16	C	D	E	A	B
Islander 17	B	C	D	E	A
Islander 18	A	B	C	D	E
Islander 19	E	A	B	C	D
Islander 20	D	E	A	B	C

Time Islander	9 am	12 pm	3 pm	6 pm	9 pm
Islander 21	B	C	D	E	A
Islander 22	A	B	C	D	E
Islander 23	E	A	B	C	D
Islander 24	D	E	A	B	C
Islander 25	C	D	E	A	B

Figure 2: Latin Square Design - Replicates

- **Held-constant variables:**
 - gender: male
 - region: town Macondo
 - age: seniors (age between 65 and 89)
- **Nuisance factors:**
 - individuals: five individuals in each Latin Square
 - time of treatment: 9 am, 12 pm, 3 pm, 6 pm, and 9 pm
- **Treatment:**
 - type of music: no music (A), Classical Music (B), Country Music (C), Dance Music (D), or Heavy Metal Music (E)
- **Replicates:**
 - sample size determination: 5 replicates of a 5 x 5 Latin Square (i.e., 25 individuals in total)

Cause-and-effect diagram for music and memory

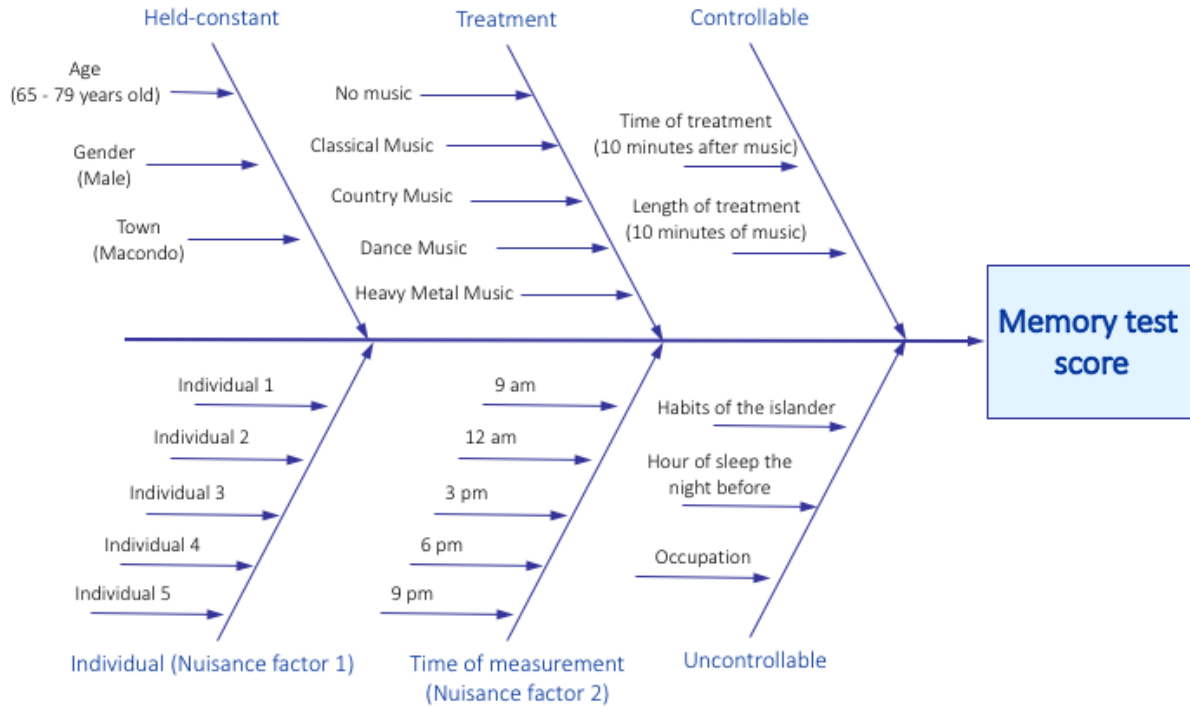


Figure 3: Cause-and-effect Diagram

- **Random assignment method:**

- (1) We assign a number from 1 to 25 to the 25 participants, then generate a random sequence (A) of number from 1 to 25 using R (`set.seed(1000)`). Then we generate a random sequence (B) of 1 to 5 (`set.seed(1000)`). We assign the participants indexed with the first five number of sequence A to the Latin Square replicate indexed with the first number in sequence B; the next five in A to the second number in B so on and so forth.
- (2) We then randomly permute the columns, randomly permute the rows, and then assign the treatments to the Latin letters in a random fashion. We ensure each treatment occur once in each row and each column.

Instruments

For this experiment, we use simulated islanders on *The Island*². We will use the different genre of music under “Music” task to assign treatment at designated time, and record performance of “Memory Test Card”. Realistically, measurement errors are introduced in the study as the time of measurement cannot be exact (e.g., 9 am sharp). However, we are allowing small measuring errors since it would not have significant impact on our final result.

²The Island: <http://island.maths.uq.edu.au>

Procedure

- (1) For each Latin Square experiment, we first measure the performance of “Memory Test Card”, then wait for 5 minutes.
- (2) Then we assign treatment according to the below diagram; after the music treatment finishes, we wait 10 minutes then perform a second “Memory Test Card” and record the result.
- (3) We replicate the above procedure for all 5 Latin Squares.

Data Analysis

Data Structure

Table 1: Structure of data collected

ID	treatment	before	after	time	difference
1	A	10	9	9:00	-1
1	E	10	8	12:00	-2
1	B	7	9	15:00	2
1	C	9	9	18:00	0
1	D	6	7	21:00	1
2	D	8	7	9:00	-1
2	C	8	5	12:00	-3
2	E	9	7	15:00	-2
2	A	8	9	18:00	1
2	B	9	9	21:00	0

Statistics of sample

Age distribution:

Firstly, we took a look at the age distribution of 25 senior male islanders that we sampled during the experiment:

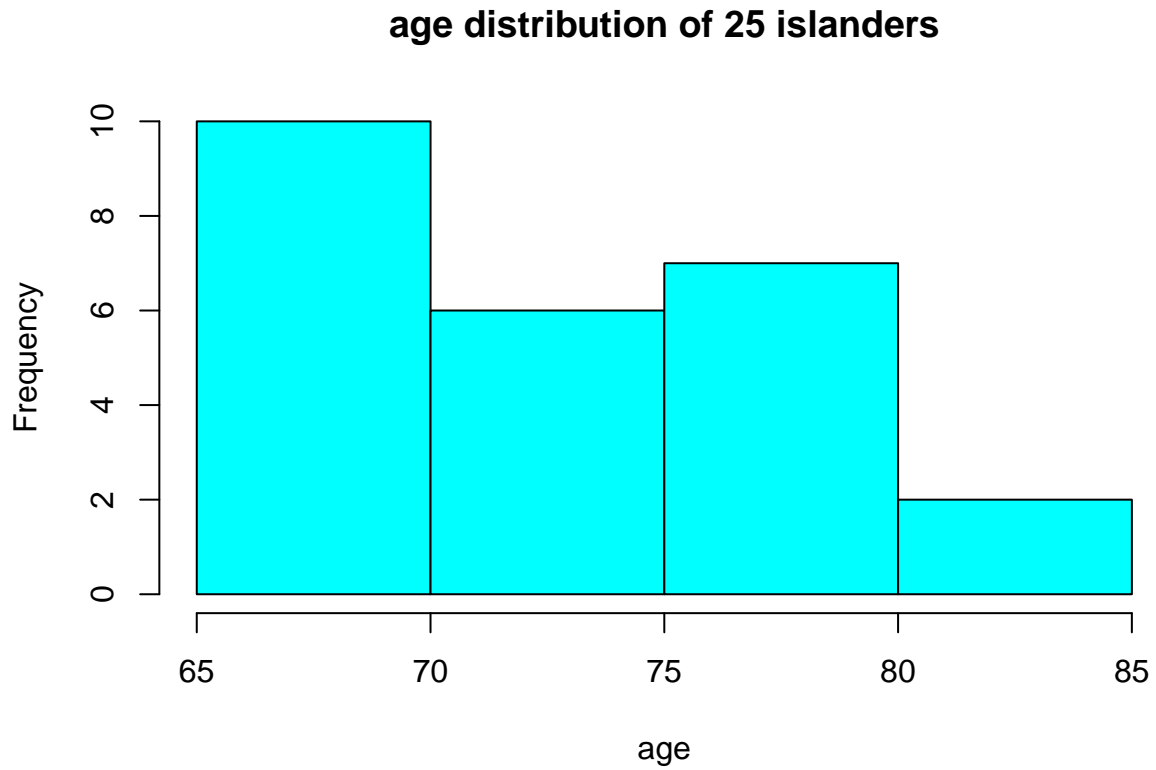


Figure 4: Age distribution of sample

Music preference:

After conducting the experiment on the Island, we also sent out a post-experiment survey to the selected 25 islanders. The purpose of this survey is to see which type of music is the islander's favorite, among all four types of music (classical, country, dance and heavy metal music).

The result of the survey is as following:

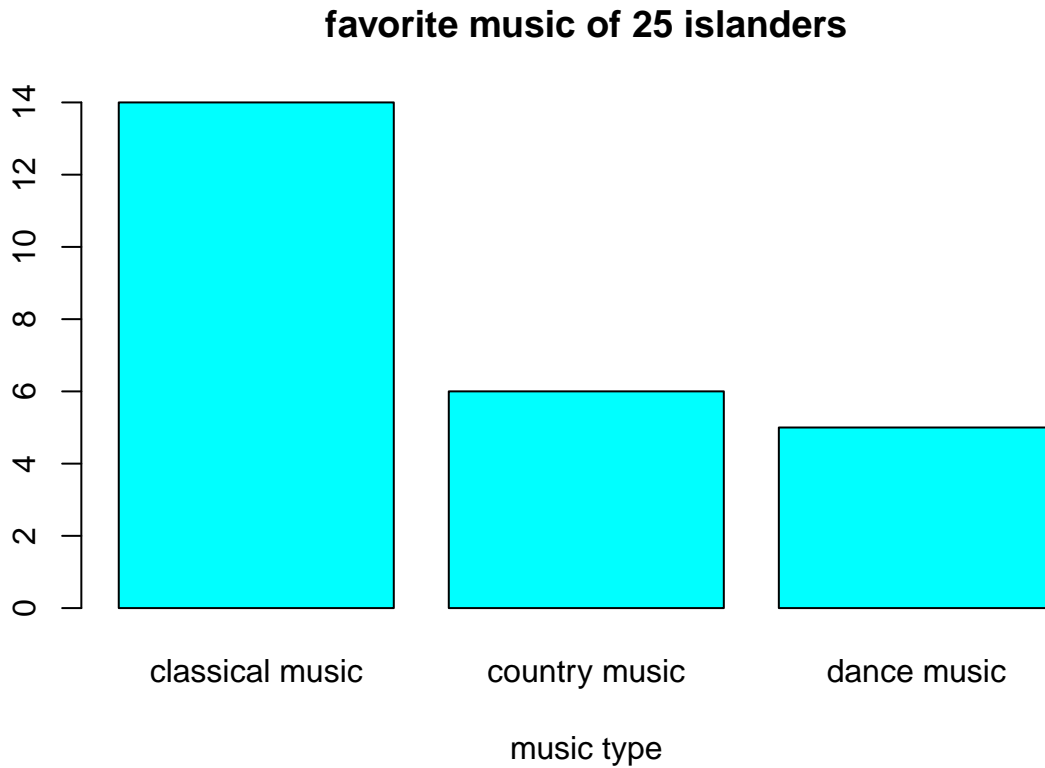


Figure 5: barplot for results of survey

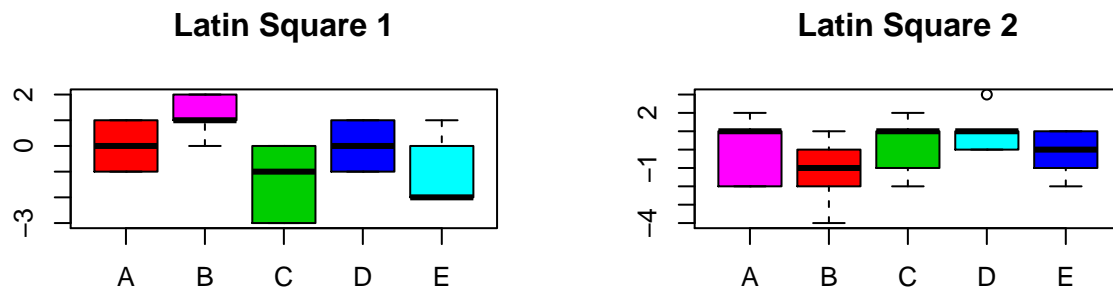
Observation:

- Age distribution: most of the senior male islanders have the age between 65 to 80 years old.
- Favorite music type: most of the islanders sampled prefer listening to classical music, while a small portion of the islanders prefer country and dance music. One important observation is that none of the 25 islanders we sampled prefer listening to heavy metal music, which may be closely connected with results.

Exploratory Data Analysis (EDA)

In this section, we did exploratory data analysis by looking at the boxplots for each Latin Square and the boxplot for all five Latin Squares combined.

Boxplot for each individual Latin Square:



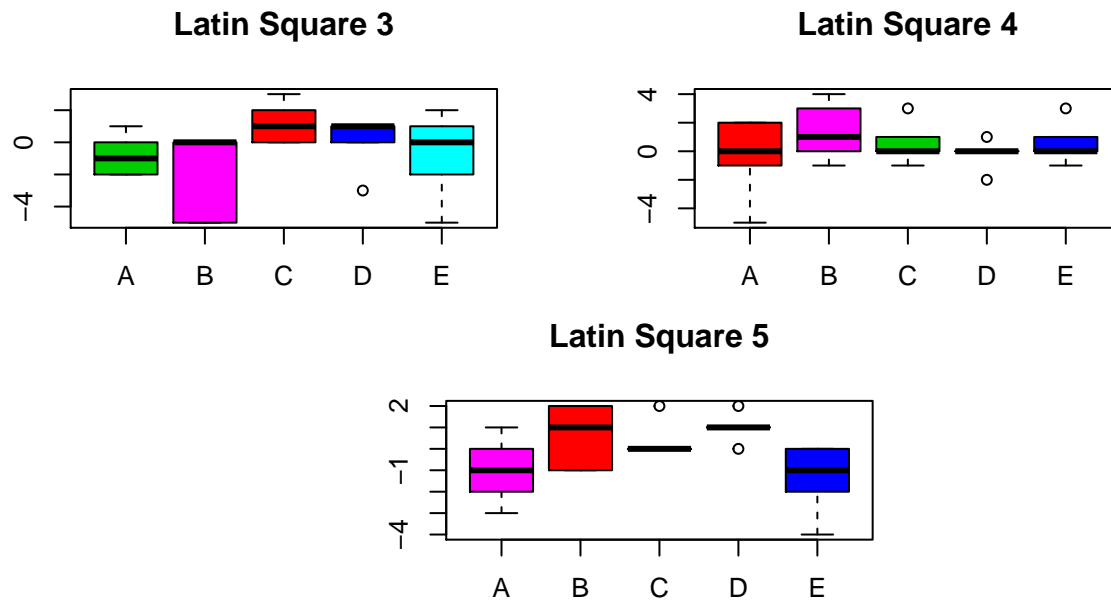


Figure 6: Boxplots for individual Latin Squares

Boxplot for all five Latin Squares combined:

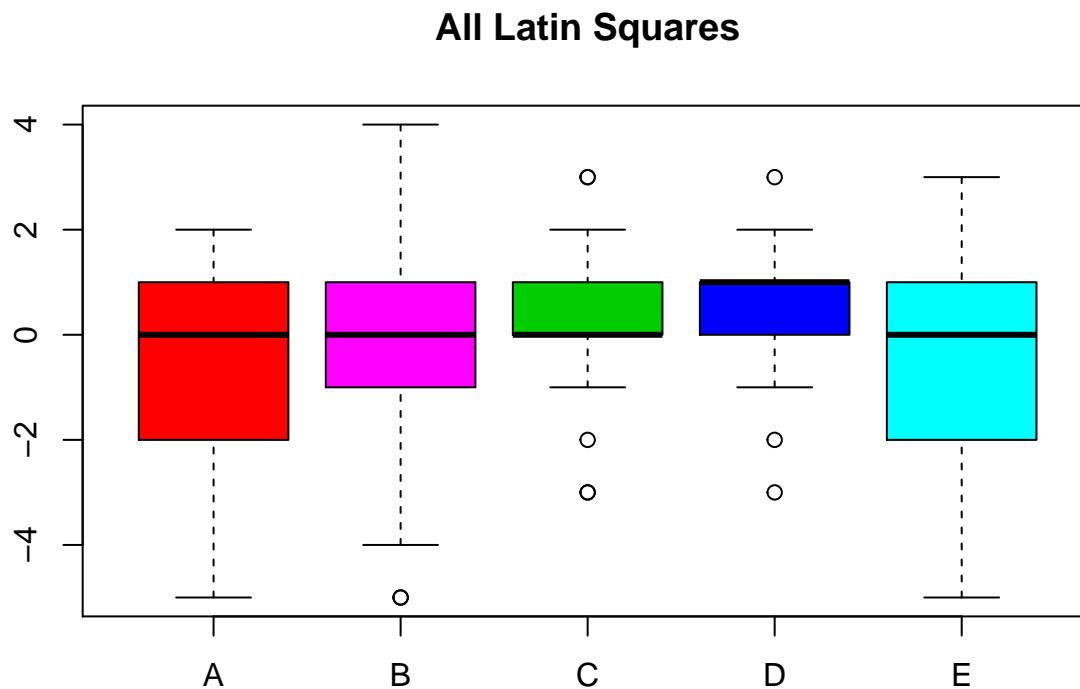


Figure 7: Boxplot for all five Latin Squares

Paired t-test

We conducted a paired t-test between the memory test score before and after the treatment.

Table 2: Paired t-test: **before** and **after**

Test statistic	df	P value	Alternative hypothesis	mean of the differences
0.562	124	0.5751	two.sided	0.088

Based on this result, our observation is that the difference between before and after the treatment is very small, which indicates that the overall result may not be very significant.

Analysis of Variance (ANOVA)

We will conduct an ANOVA test on the results collected. We will first load the data into R and use `aov()` function to analyze if there is any difference among the effects of different genre of music on memory retention in male aged 65 to 79, among all five 5 x 5 Latin Squares in data collected.

In this process, we will use paired t-test to determine if there is any significant difference among the different groups of genres of music and disregard the interactions between nuisance variables. That is to say, we will obtain the degrees of freedom, sum of squares and mean sum of squares for row and column blocks, the treatment, and their **F-value** and **p-value** in the summary statistics.

We divided our analysis of variance (ANOVA) into two sections:

- in the first part, we looked at the ANOVA table for each individual Latin Square;
- in the second part, we investigated the ANOVA table for all five Latin Squares combined.

Part 1: ANOVA of five individual Latin Squares:

Latin Square 1:

Table 3: Analysis of Variance Table for Latin Square 1

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
treatment	4	20.56	5.14	8.965	0.001365
ID	4	8.56	2.14	3.733	0.03387
time	4	12.56	3.14	5.477	0.009582
Residuals	12	6.88	0.5733	NA	NA

Latin Square 2:

Table 4: Analysis of Variance Table for Latin Square 2

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
treatment	4	12.56	3.14	0.9691	0.4596
ID	4	6.56	1.64	0.5062	0.7323
time	4	6.96	1.74	0.537	0.7115
Residuals	12	38.88	3.24	NA	NA

Latin Square 3:

Table 5: Analysis of Variance Table for Latin Square 3

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
treatment	4	27.84	6.96	1.772	0.1992

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ID	4	29.04	7.26	1.849	0.1844
time	4	10.24	2.56	0.652	0.6365
Residuals	12	47.12	3.927	NA	NA

Latin Square 4:

Table 6: Analysis of Variance Table for Latin Square 4

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
treatment	4	10.4	2.6	1.04	0.4266
ID	4	10.4	2.6	1.04	0.4266
time	4	33.2	8.3	3.32	0.0475
Residuals	12	30	2.5	NA	NA

Latin Square 5:

Table 7: Analysis of Variance Table for Latin Square 5

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
treatment	4	22.24	5.56	4.088	0.02564
ID	4	5.84	1.46	1.074	0.4118
time	4	13.44	3.36	2.471	0.1009
Residuals	12	16.32	1.36	NA	NA

Part II: ANOVA for all five Latin Squares:

All five Latin Squares:

Table 8: Analysis of Variance Table for five Latin Squares

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
treatment	4	15.95	3.988	1.277	0.2849
ID	24	70.83	2.951	0.9448	0.5436
time	4	5.872	1.468	0.47	0.7576
Residuals	92	287.4	3.124	NA	NA

Table 9: Effects of the treatment

A	-0.352
B	0.088
C	0.288
D	0.448
E	-0.472

Table 10: Effects of individuals (continued below)

1	2	3	4	5	6	7	8	9
0.088	-0.912	0.088	-0.712	0.688	0.088	-0.712	-0.112	0.088

Table 11: Table continues below

10	11	12	13	14	15	16	17	18
0.888	0.688	-0.312	-1.712	-1.512	0.888	-0.512	0.488	1.488

19	20	21	22	23	24	25
0.688	0.288	0.488	-0.512	0.688	-0.312	-0.312

Table 13: Effects of time

12:00	-0.192
15:00	0.128
18:00	0.008
21:00	0.328
9:00	-0.272

Based on the ANOVA table obtained above, we observe that:

- Among all five individual Latin Squares, music treatment in Latin Square 1 and Latin Square 5 have significant effects on improving memory test score.
- However, music treatment is not significant when we combine all five Latin Squares together.

To explore more about which music treatment is more helpful for improving memory test score on islanders, we conducted multiple groups comparison tests on Latin Square 1 and Latin Square 5.

Multiple groups comparison

From the last section, we observe that music treatment is indeed significant in Latin Square 1 and 5. To see which music plays a more important role in improving the memory test score, we did multiple groups comparison on each of the two squares, using **Tukey HSD** method.

Multiple groups comparison for Latin Square 1:

95% family-wise confidence level

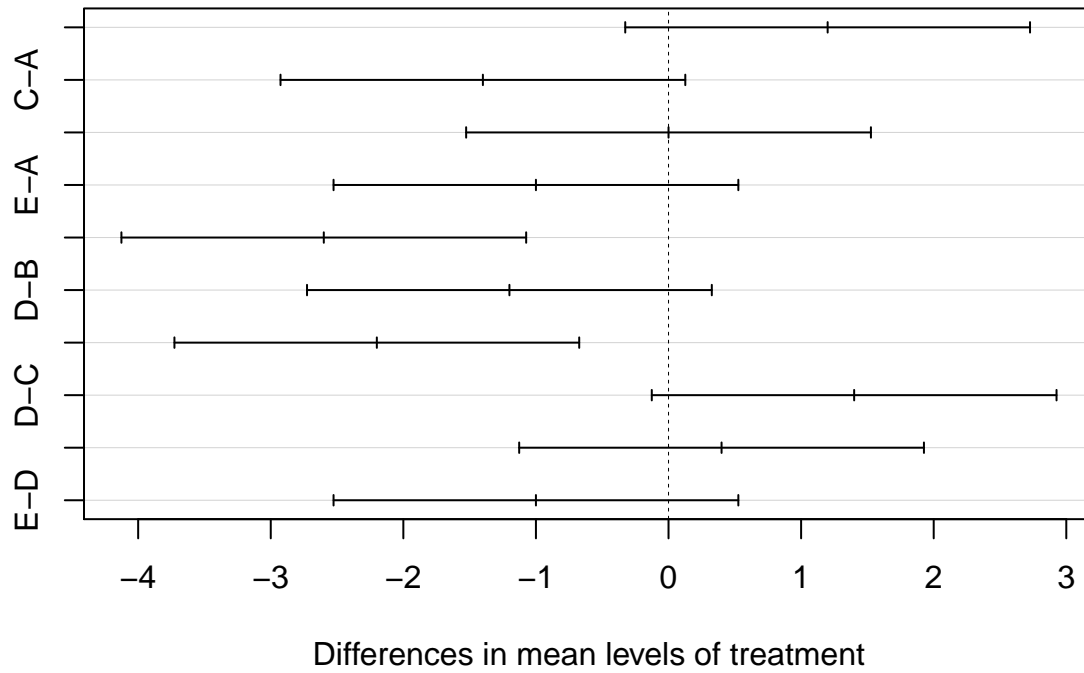


Figure 8: Multiple groups comparison on Latin Square 1

Multiple groups comparison for Latin Square 5:

95% family-wise confidence level

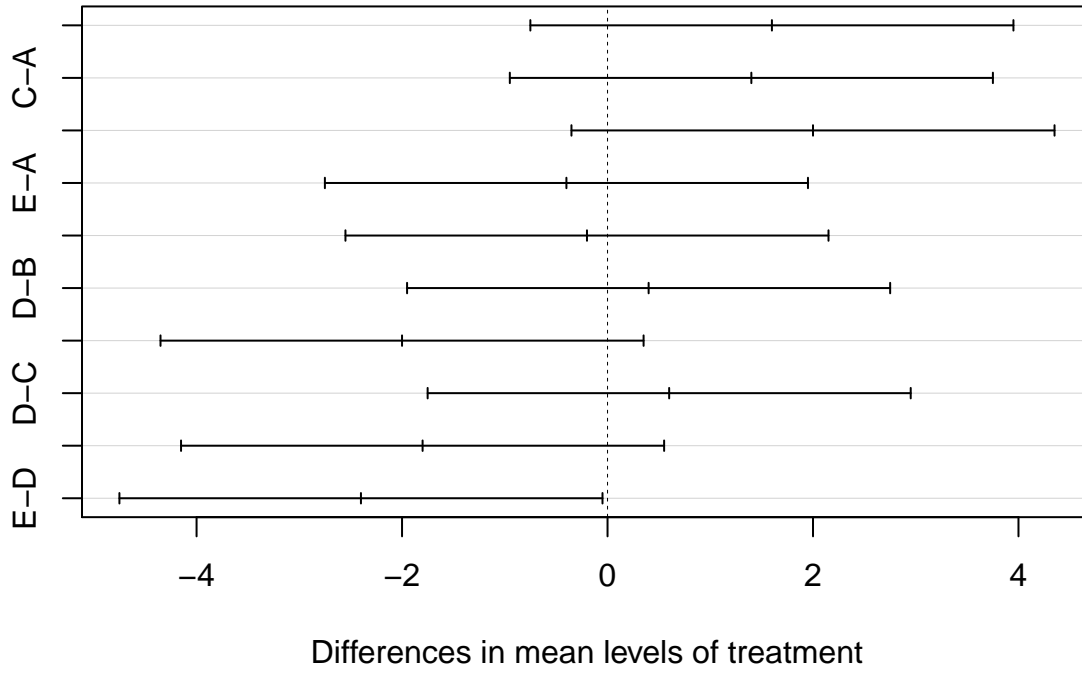


Figure 9: Multiple groups comparison on Latin Square 5

Based on the multiple groups comparison, we observe that:

- In Latin Square 1:
- In Latin Square 2:

Model assumption checking

Model:

$$y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \epsilon_{ijk}, \text{ where } i, j, k = 1, 2, 3, 4, 5$$

Assumption checking:

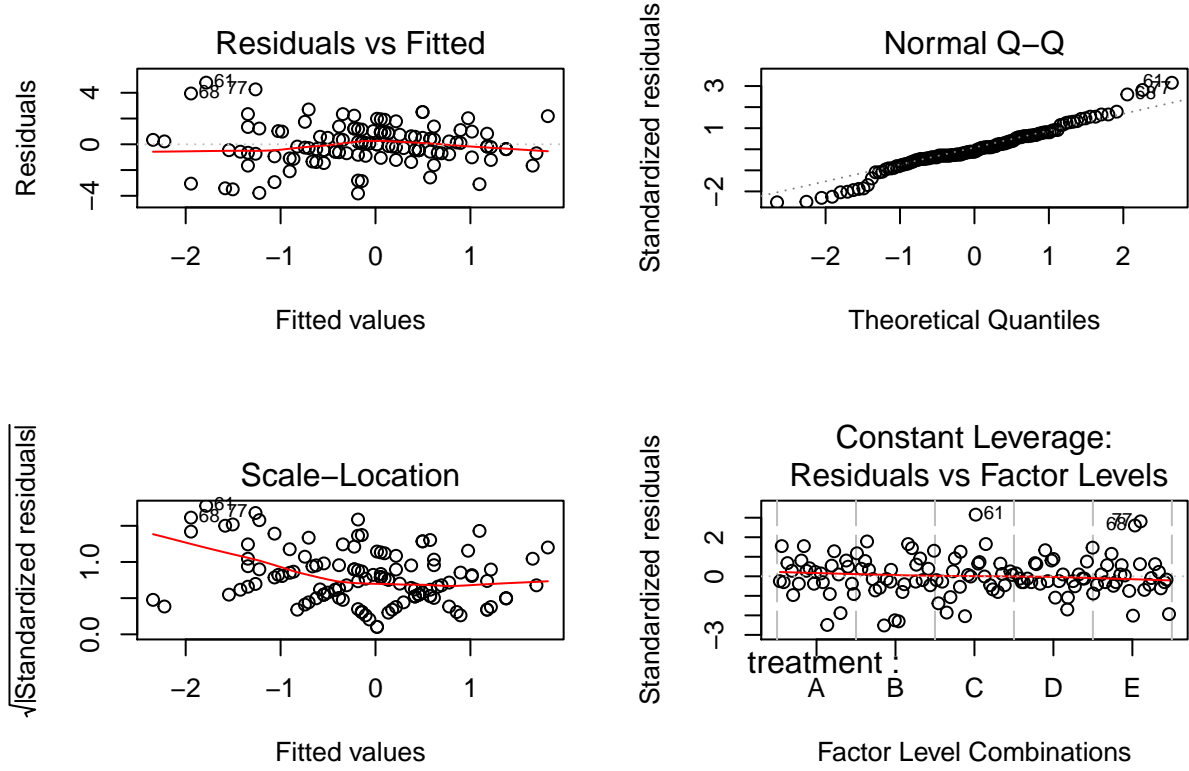


Figure 10: Diagnostics plots for model $\text{difference} \sim \text{treatment} + \text{ID} + \text{time}$

- Based on the residuals vs. fitted values plot, we observe that there is no certain pattern in the graph, and the average value of error terms is mostly around zero. This indicates that the assumption of independent error terms with average value of zero is satisfied.
- Based on the normal QQ-plot, we observe that most of the data points are around the 45-degree line through the origin. This indicates that the assumption of normally distributed error terms is mostly satisfied.
- Based on the $\sqrt{\text{standardized residuals}}$ vs. fitted values plot, we observe that there is a slightly decreasing trend in the value of $\sqrt{\text{standardized residuals}}$. This indicates that the assumption of constant variance of error terms is slightly violated.

Conclusion

To be finished.

Discussion

- Since we choose to sample senior islanders in the experiment, we consider sampling senior female islanders in the future to have further investigation on whether music has effects on memory.
- Based on the post-experiment survey, we discovered that most of the senior islanders prefer listening to classical and country music. This provides motivation for further studies on the relation between favorite type of music, music treatment, and memory test score.

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