Department of Mathematics and Statistics
University of Victoria

How to Improve the Short-term Memory

STAT453 Final Project

Siying Ma V00948454
Xun Tan V00897477
Lingling Lin V00023220
Xiaotong Guo V00898642

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1 Introduction

1.1 Research problem

With the development of science and technology, it is very common for every university student to have a computer. No matter what you do, you can solve it by searching on Google, and you do not need to remember everything. Lots of lectures in the university do not have plenty of compulsory recitations, and rarely use memory. Therefore, the ability to memorize of university students is in a slow development stage and there is no substantial improvement. Therefore, we must make good use of the rules of memory and use scientific methods to enhance memory and improve learning skills.

Some sets of research results indicating that several factors may affect short-term memory. For instance, listening to baroque's music may induce a short-term improvement on the performance of certain kinds of mental tasks[2]. Also, the people who eat snacks like blueberry will have a better performance on recalling past events[1]. In addition, running can improve your mind at any age and fight age-related cognitive decline. A review of research on the cognitive-boosting effect of exercise found that running improved working memory and focus[3, 7]. Researchers found that rolling eyes horizontally from left to right for 30 seconds or meditating for 10 minutes improves performance on memory tasks as well[6]. A few researchers like Kathleen and Allison also found that chewing gum can help the brain release alpha waves, reduce tension and anxiety, improve learning ability, concentration and information absorption[4, 5].

For all these factors which can affect short-term memory, we have conducted an experiment to determine which of the factors among music, sport and gum would result in improving short term memory.

1.2 Possible factors

- Do sport
- Chew gum

- Listen to music
- Eat breakfast or not
- Use images to memorize
- Write the numbers down
- Read the numbers loudly
- Meditate for 10 minutes
- Eat blueberry before the experiment
- Roll eyes horizontally from left to right for 30 seconds

2 Design of experiment

2.1 Factor selection and levels

In this experiment, we need to try the best to improve our short-term memory. From the previous research, it is shown that listening to music, doing sport and chewing gum seem to be effective in this case, therefore, we identify these three factors as the main treatments in our experiment. Also, we choose a typical baroque music as the treatment of music, jogging as the way of sports and a specific flavour of gum to reduce the bias when imposing the treatments. Since our goal is to see whether these factors can work or not, we assign *without this factor* to the low level and *with this factor* to the high level.

Table 1: Factors and Levels for the Short Term Memory Experiment

Factors	Type	Low	High
Music	categorical	No	Yes
Sport	categorical	No	Yes
Gum	categorical	No	Yes

Asides from the design factors, there still have some constant factors to help us keep the results as accurate as possible.

- The time of each experiment
- The location of each experiment
- The length of each experiment

However, we still have some nuisance factors that may affect our results significantly.

- Subjects' initial memory
- Subjects' daily activities

2.2 Selection of response variable

Referring to the World Memory Championships, one of the event is to remember the random digit as much as possible in a scheduled time. We follow this rules and set the response variable as the number of correct digits. We use the Table of Random digits *[link]* as the material of our experiments and randomly select eight rows for the eight treatment combination. We set up the scheduled time as two minutes each time and calculate the number of the correct digits from the first one to the one before the first wrong digit.

2.3 Choice of experimental design

Referring to Table 1, the selected three factors are categorical factors with both low and high levels. In order to analyze them, we convert them to numeric and assign the capital letters to each factor.

Table 2: Factors and Levels for the Short Term Memory Experiment

Factor	Low	High
A: Music	-1	1
B: Sport	-1	1
C: Gum	-1	1

The experiment will be performed by a 2^3 factorial design. We need to measure the effect of each factor at different levels and to see which combination will result in the most significant

effect on the improvement of the short-term memory. Since it is possible that imposing two factors at the same time will be more effective, we also test the interaction in our experiment. We design our experiment by the matrix below.

Table 3: The Design Matrix for the Short Term Memory Experiment

Treatment	Factorial Effect							
Combination	I	A	B	AB	C	AC	BC	ABC
(1)	+	-	-	+	-	+	+	-
a	+	+	-	-	-	-	+	+
b	+	-	+	-	-	+	-	+
ab	+	+	+	+	-	-	-	-
c	+	-	-	+	+	-	-	+
ac	+	+	-	-	+	+	-	-
bc	+	-	+	-	+	-	+	-
abc	+	+	+	+	+	+	+	+

The measurement of response variable is based on the subjects' performances in the experiment which always varies from person to person, so it has a great possibility that the bias will be very large if we just take a single replicate design. It is necessary to replicate the experiment with several people. Therefore, we randomly select four students in the University of Victoria as the volunteer of our experiment, i.e n=4. And the total number of run is equal to $2^3 \times 4 = 32$ runs.

To avoid the errors from the subjects' psychological hints made by the order of runs of experiment, we apply the simple random method to assign the order of the runs to each subject and won't tell them until they need to do this experiment.

Referring to the last paragraph of 2.1, the main nuisance factors are the subjects' initial memory and their daily activities. Since the ability to remember the random numbers and their states affected by their daily routines differs from person to person, we will treat each subject as a block to minimize the effects of nuisance factors.

3 Data collection

3.1 Procedure of the experiment

1. Verify all materials are ready with us such as baroque's music, gum and four sheets of different sets of numbers.
2. Be ready in the gym at 5:00 p.m. on four days.
3. Each team member will choose one treadmill.
4. Each team member will be assigned the same sheets with different sets of numbers.
5. Each team member starts to conduct the experiment by following the different order with different treatment combinations that we picked randomly.
6. Each team member will have two minutes to memorize as many numbers as they can.
7. When time is over, each team member writes down all numbers and record the number of correct numbers until the first incorrect number appears.
8. After 10 minutes break, they start another round.
9. Collect and record all data 32 times from four volunteers.

3.2 Issues in the experiment

There may exist several factors affect the results of experiment. We interrupted once experiment due to the surrounding environment noise. After returning to the normal environment condition, we get back to the experiment.

3.3 Data

Table 4: Observations and Randomized Run Order for the Short Term Memory Experiment

Treatment Combination	Main Effect			Subject(Run Order)			
	A:Music	B:Sport	C:Gum	Block1	Block2	Block3	Block4
(1)	-	-	-	20(2)	20(1)	23(3)	11(6)
a	+	-	-	25(7)	30(7)	30(8)	23(3)
b	-	+	-	25(5)	25(8)	25(6)	20(4)
ab	+	+	-	25(8)	30(3)	24(1)	30(2)
c	-	-	+	8(3)	11(5)	13(7)	10(5)
ac	+	-	+	18(1)	15(4)	15(2)	20(7)
bc	-	+	+	15(4)	15(6)	13(4)	23(8)
abc	+	+	+	15(6)	21(2)	20(5)	14(1)

4 Linear model

By running the experiment, we obtain 32 response data that is added to the design matrix according to their runs order. We perform the statistical analysis by using R to obtain regression table, ANOVA table, the normal QQ-plot, the residual vs fitted value plot, cube plot and interaction plot. Each of the analysis is explained below.

4.1 The 2^3 factorial design

First, we write down the statistical model for this experiments.

$$y_{ijkl} = \mu + \tau_i + \beta_j + \gamma_k + (\tau\beta)_{ij} + (\tau\gamma)_{ik} + (\beta\gamma)_{jk} + (\tau\beta\gamma)_{ijk} + \epsilon_{ijkl}, \quad \begin{cases} i, j, k = 1, 2 \\ l = 1, 2, 3, 4 \end{cases}$$

where μ is the overall mean, τ_i is the effect of Music in the ith level, β_j is the effect of Sport in the jth level, γ_k is the effect of Gum in the kth level and the left are the effects of the two-term and three-term interactions.

Now, we begin the analysis by running the full model consisted of all three main effects: Music, Sport, Gum and all the interactions. Based on both the results of linear model in Table 5 and the ANOVA results in Table 6, since the p-value of music, sport and gum are all < 0.05, we can conclude that the main effects of music, sport and gum are significant. Furthermore, there

Table 5: Regression Analysis for the Short Term Memory Experiment

Coefficients	Estimate	Std. Error	t_0	p-value
(Intercept)	19.7500	0.6203	31.840	< 0.0001
Music	2.4375	0.6203	3.930	0.000629
Sport	1.5000	0.6203	2.418	0.023551
Gum	-4.3750	0.6203	-7.053	< 0.0001
Music:Sport	-1.3125	0.6203	-2.116	0.044917
Music:Gum	-0.5625	0.6203	-0.907	0.373514
Sport:Gum	0.1250	0.6203	0.202	0.841993
Music:Sport:Gum	-0.0625	0.6203	-0.101	0.920579

is a significant interaction between music and sport because the p-value < 0.05.

Table 6: Analysis of Variance for the Short Term Memory Experiment

Source of Variation	DF	Sum of Squares	Mean Square	F_0	p-value
Music	1	190.1	190.1	15.442	0.000629
Sport	1	72.0	72.0	5.848	0.023551
Gum	1	612.5	612.5	49.746	< 0.0001
Music:Sport	1	55.1	55.1	4.477	0.044917
Music:Gum	1	10.1	10.1	0.822	0.373514
Sport:Gum	1	0.5	0.5	0.041	0.841993
Music:Sport:Gum	1	0.1	0.1	0.010	0.920579
Residuals	24	295.5	12.3		

We can first check the model assumption of the full model. From the normal QQ-plot (Figure 5 in Appendix), the points lie along the straight line, so the plot does not reveal problem with normality assumption. By Shapiro-Wilk test, the p-value is 0.3435 (> 0.05), indicating normality. The residuals scatter randomly (Figure 6 in Appendix), so the plot does not indicate any problem with constant variance.

From Table 5 and Table 6, we know interaction Music:Gum, Sport:Gum and Music:Sport:Gum are not significant. Also from Table 7, we can find that the percent contributions of the effect of these factors are really low, so we can just ignore them. After removing them, we can refit the model.

Table 7: Effect Estimate Summary for the Short Term Memory Experiment

Treatment	Effect Estimate	Sum of Squares	Percent Contribution
A	4.875	190.125	15.382
B	3	72	5.825
C	−8.750	612.500	49.555
AB	−2.625	55.125	4.460
AC	−1.125	10.125	0.819
BC	0.250	0.500	0.040
ABC	−0.125	0.125	0.010

From Table 8 and Table 9, we can find that the p-value of all the factors are > 0.05, so we can conclude that all the factors in this model are significant. The reduced model is that

$$y = 19.75 + 2.4375\text{Music} + 1.5\text{Sport} - 4.375\text{Gum} - 1.3125\text{Music} \times \text{Sport}$$

Table 8: Regression Analysis for the Short Term Memory Experiment(Significant factors only)

Coefficients	Estimate	Std. Error	t_0	p-value
(Intercept)	19.7500	0.5954	33.173	< 0.0001
Music	2.4375	0.5954	4.094	0.000345
Sport	1.5000	0.5954	2.519	0.017977
Gum	−4.3750	0.5954	-7.348	< 0.0001
Music:Sport	−1.3125	0.5954	-2.205	0.036192

Table 9: Analysis of Variance for Short Term Memory Experiment (Significant factors only)

Source of Variation	DF	Sum of Squares	Mean Square	F_0	p-value
Music	1	190.1	190.1	16.762	0.000345
Sport	1	72.0	72.0	6.348	0.017977
Gum	1	612.5	612.5	54.000	$<$0.0001
Music:Sport	1	55.1	55.1	4.860	0.036192
Residuals	27	306.3	11.3		

Normality assumption seems good by QQ-plot (Figure 1) and by Shapiro-Wilk test, the p-value is 0.8309 (> 0.05), indicating normality. Moreover, since there is no distinct pattern in residual vs fitted plot(Figure 2), the constant variance assumption is also valid.

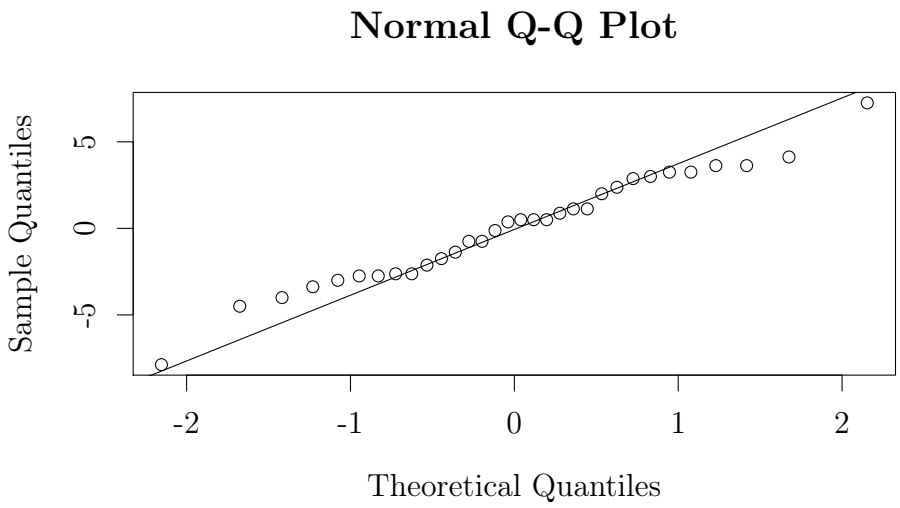


Figure 1: Normal QQ-plot of residuals for the reduced model

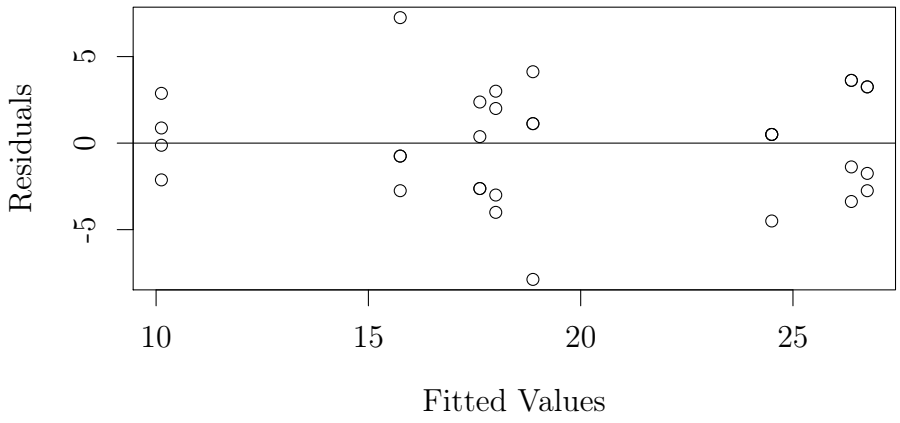


Figure 2: Plot of residuals versus fitted value for the reduced model

4.2 Blocking a replicated 2^3 factorial design

Since there are four people doing this experiment, in order to minimize the effects of nuisance factors,we use randomized complete block design (RCBD) to construct the design in four blocks with eight runs each.

Table 10: Analysis of Variance for the Short Term Memory Experiment (with block)

Source of Variation	DF	Sum of Squares	Mean Square	F_0	p-value
Music	1	190.1	190.1	14.787	0.00094
Sport	1	72.0	72.0	5.600	0.02765
Gum	1	612.5	612.5	47.639	<0.0001
Block	3	25.5	8.5	0.661	0.58514
Music:Sport	1	55.1	55.1	4.287	0.05091
Music:Gum	1	10.1	10.1	0.787	0.38491
Sport:Gum	1	0.5	0.5	0.039	0.84557
Music:Sport:Gum	1	0.1	0.1	0.010	0.92239
Residuals	21	270.0	12.9		

From Table 10, we can conclude that main factor music, sport and gum are significant for the model with block since the p-values for these are < 0.05. Also, we can find that the p-value for the interaction between music and sport is 0.05091, which is almost equal to 0.05, so we define this factor as a a significant one too. However, block seems not important for the model in this experiment because in Table 10, p-value is $0.58514 > 0.05$.

Above all, we conclude the final model is that

$$y = 19.75 + 2.4375\text{Music} + 1.5\text{Sport} - 4.375\text{Gum} - 1.3125\text{Music} \times \text{Sport}$$

By finding the maximum of fitted value in full model, we know that music and sport in the high level and gum in the low level will improve short term memory.

4.3 Interaction analysis

We also can verify the conclusion of improving short term memory with the cube plot and the interaction plot.

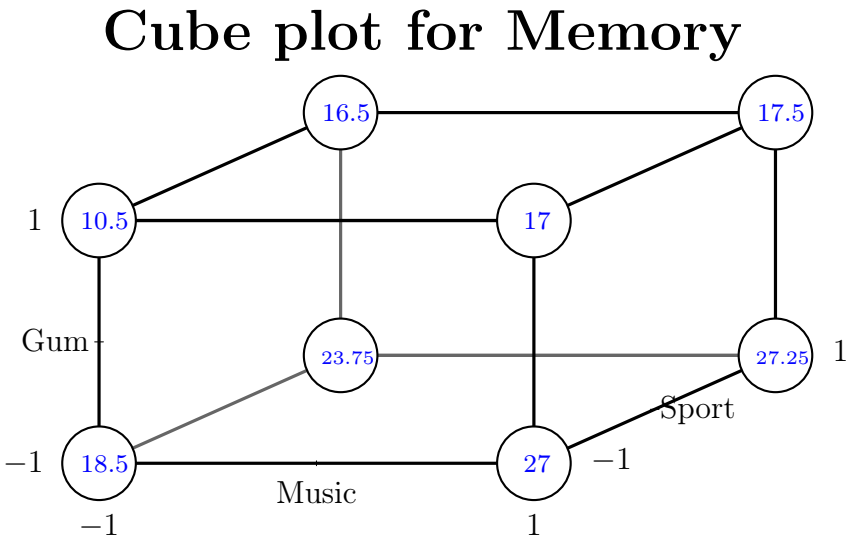


Figure 3: Cube plot of music, sport and gum for Table 6

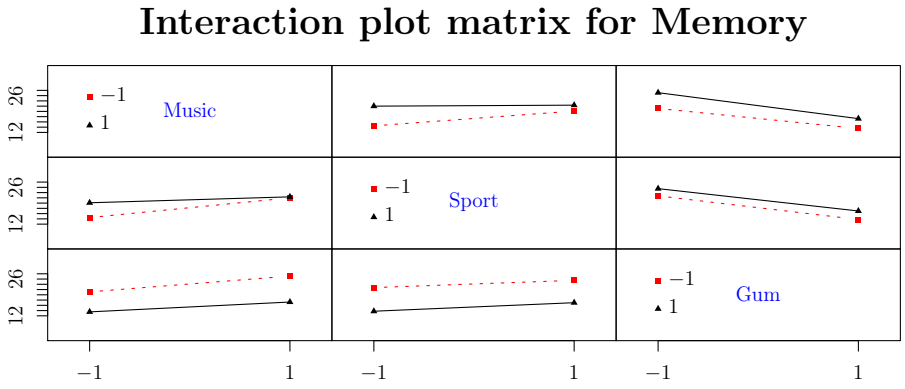


Figure 4: Interaction plot for Table 6

5 Conclusion

We have conducted an experiment to determine which of the factors among music, sport and gum would result in improving short term memory. Based on our ANOVA analysis, we have concluded that music, sport, gum, and interaction between music and sport are significant in our model, which means that music, sport, gum and the combination of music and sport most affected the short term memory.

As predicted, we would expect music and sport would give better results in memory. Surprisingly, chewing gum would not help improve the memory in this experiment. To obtain a better model, we consider the different people doing an experiment as a nuisance factor at the beginning, then we try to add blocks to reduce the negative effect. However, we found that block is not necessary for our model which means variation between different volunteers in this experiment can be ignored.

Our recommendations for people who want to improve short term memory as possible are to listen to music (baroque) during memorization and run a couple of minutes before memorization. In future experimentation, we suggest incorporating more levels in main factors that can potentially improve the short term memory.

6 Appendix

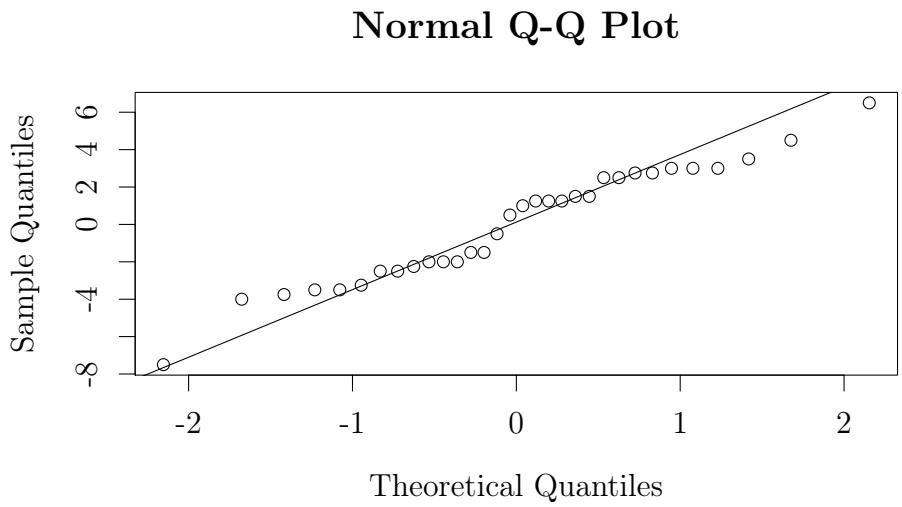


Figure 5: Normal Q-Q Plot for full model

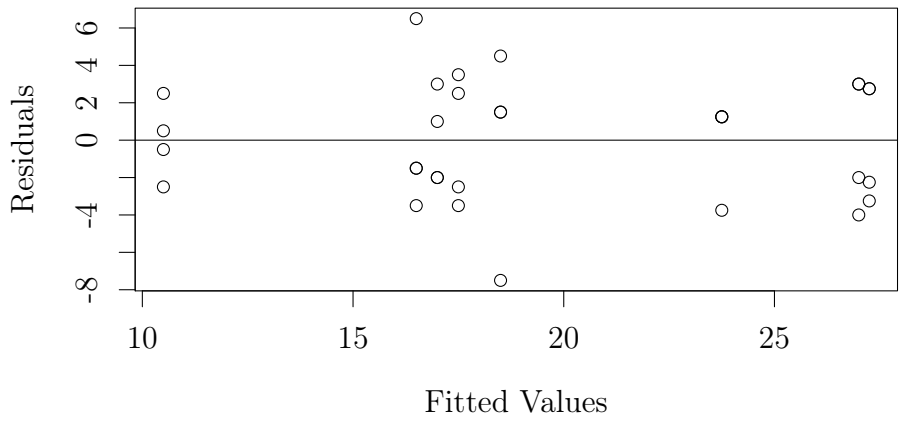


Figure 6: Plot of residuals versus fitted value for full model

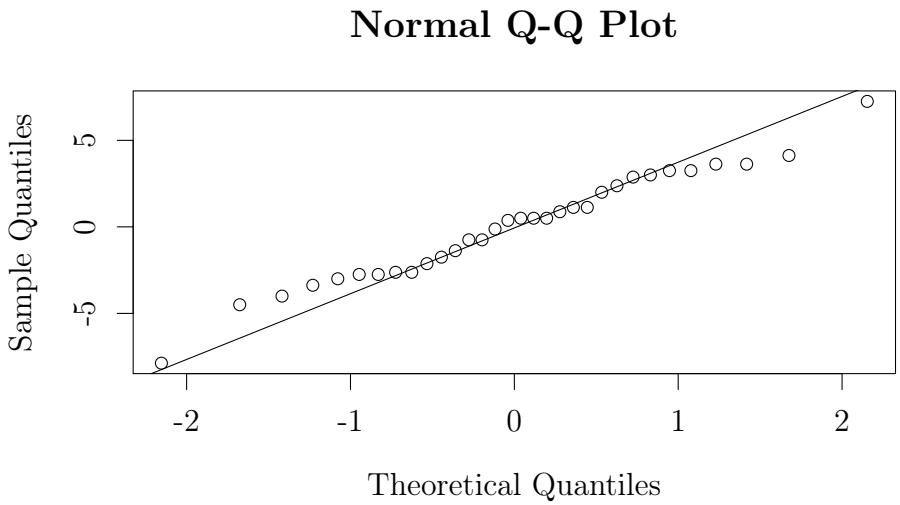


Figure 7: Normal Q-Q Plot for reduced model

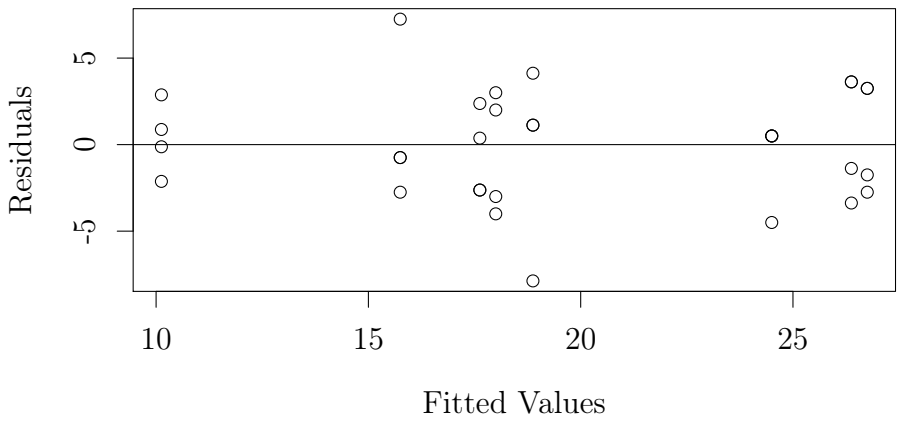
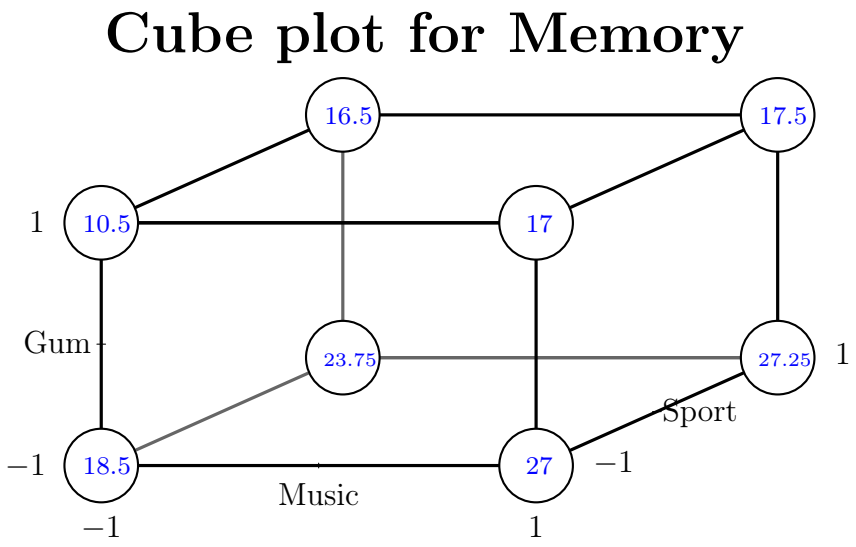
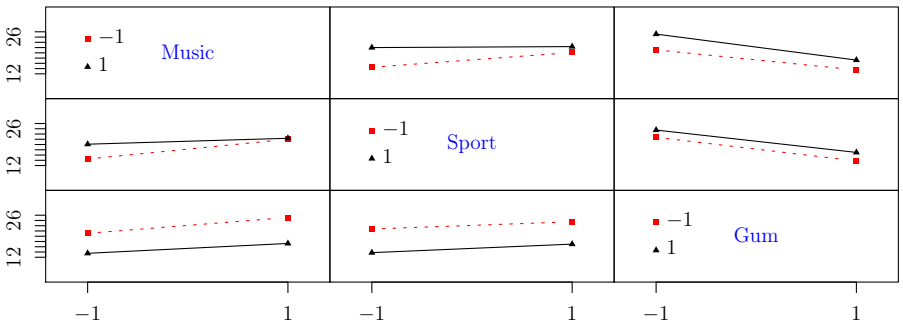


Figure 8: Plot of residuals versus fitted value for reduced model


Cube plot for Memory
16.5
17.5
1
10.5
17
Gum
23.75
27.25
1
Sport
−1
18.5
27
−1
Music
−1
1


Interaction plot matrix for Memory
Music
Sport
Gum
−1
1
12
26

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