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Action Games and Mental Activity during the Different Cycles in the Circadian Rhythm

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Executive Summary

Humans have a daily biological clock called the Circadian Rhythm, which dictates the alertness and sleepiness of humans in a 24-hour period. Approximately between 1:30 and 4 PM, people experience a decreased mental alertness called post-lunch dip (PLD). During post-lunch dip, people feel sleepy. Because of their sleepiness, their productivity decreases. This study investigated countering the PLD effect through action-game-induced adrenaline rush. It also investigated the effect of action-game-induced adrenaline rush to mental alertness at non-PLD times in the morning.

Two engineering students were selected as respondents and asked to participate in the study. They were asked to play a fast-paced game of Tetris, and then to multiply 3-digit by 3-digit numbers during their morning alertness peak (MAP), their decreasing morning alertness (DMA), and their PLD. The time it took them to correctly multiply the pair of numbers were recorded and compared to the time it took them to correctly multiply a different pair of numbers when they did not play Tetris before solving during their MAP, their DMA, and their PLD. It was assumed that the time it took to multiply a pair of numbers implies a level of mental alertness. A split-plot design was used to analyze the effects of the factors. To ensure that the difficulty of different pairs of 3-digit numbers, six pairs were randomly produced, ensuring that all numbers had no zero digit in them, and that once a digit had been used, it would not be used anymore within a pair. Furthermore, two respondents different to the previously mentioned were asked to solve the six pairs of numbers. The time it took them to solve each pair of numbers were recorded. These were analyzed using a complete randomized block design. A comparison of means was used to determine if playing Tetris had decreased the time of multiplying correctly a pair of numbers during PLD.

The analyses of the different designs revealed that playing Tetris did not affect the time to correctly multiply a pair of numbers. It was also found out that the time to correctly multiply pairs of numbers is not affected by the degree of mental alertness of the respondents.

The time it took for the respondents to correctly multiply the pairs of numbers might not be a good indicator of mental alertness. Tetris might not be exciting enough to produce an adrenaline rush to increase mental alertness and counter PLD. Multiplying pairs of numbers is too simple for alertness to affect, especially if the respondents are used to more complicated mathematical problems.

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1. Introduction

Humans have an internal biological clock. This biological clock is found in the suprachiasmatic nuclei (SCN) region in the brain's hypothalamus [Figure Appendix-1]. "The SCN is made up of two tiny clusters of several thousand nerve cells that 'tell time' based on external cues, such as light," temperature, or other input from the environment. The SCN produces rhythmic chemical signals to regulate sleep, metabolism, body temperature and hormone production that is based on external cues that the SCN receives [1-2]. The daily rhythmic production of chemical signals is called the Circadian Rhythm.

After lunch, body temperature decreases, and humans experience a period of decreased alertness between 1-4PM. This period is called a post-lunch dip (PLD). PLD happens whether a person eats lunch or not, but a heavy lunch can aggravate this. During PLD, "work performance suffers, people in dimly lit meeting rooms are apt to nod off, and the likelihood of getting into a car accident increases [2]." PLD can be countered by drinking coffee then taking a 20-minute nap (Caffeine takes 20 minutes to take effect [4]), by walking briskly outside, by drinking ice-cold juice, or by "doing work that requires moderate physical exertion [2]." There are instances, such as working in a library, when it's not practical to drink the suggested beverages, to take brisk walks, to nap for 20 minutes, or to do work with moderate physical exertion. There are also people who don't drink caffeinated beverages.

Action games are electronic or computer games that challenge the reflexes and coordination ability of its players [5]. Action games also induce an adrenaline rush to its players [6] causing them to be energized. They are easily accessible; they are found in desktop computers, laptops, personal digital assistants (PDAs), mobile phones and handheld game consoles (e.g. Nintendo's Gameboy).

1.1. Objectives

This study explored the possibility of using action games to induce an adrenaline rush to counter PLD. This study also investigated the effect of induced adrenaline rush by playing action games to alertness at non-PLD times.

1.2. Methodology

Two randomly selected people were asked to participate in this study. Their natural rhythm of alertness and sleepiness over a 24-hour period were determined by using the Daily Rhythm Test found in BBC's website [4]. The respondents were asked to answer a questionnaire from the BBC's website (Figure Appendix-2). Their replies to the questions were keyed in, and their natural rhythm of alertness and sleepiness over a 24-hour period were displayed as a graph (Figure Appendix-3 and 4).

The respondents were asked to play a handheld electronic action game of Tetris¹ set at its highest possible speed, which was hoped to produce an adrenaline rush to the respondents that would consequently increase their alertness. After playing a game, the respondents were asked to then manually multiply a random 3-digit number by another random 3-digit number during three different times in their natural rhythm: morning alertness peak (MAP), decreasing morning alertness (DMA), and PLD. The respondents answer a different randomly selected set of multiplication problem for each treatment. Since there are six different treatments, there are six different sets of multiplication problem; one for each treatment. The time it took for them to answer correctly the multiplication problems were recorded, and compared to the time it took for them to answer correctly another 3-digit-by-3-digit multiplication problem after not playing the action game during their MAP, during their DMA, and during their PLD. The split-plot design is the most appropriate design for this experiment (Table 1-1). A discussion of the split-plot design can be found in Montgomery [8]. The numbers in the parentheses are the run orders.

¹ "Tetris is a computer game invented by Alexey Pajitnov in 1985, while he was working for the Academy of Sciences in Moscow, inspired by a pentominoes game he had purchased earlier. Tetrominoes or tetrads, shapes composed of 4 blocks each, are falling down the screen, and one has to direct them so they will fit to the wall on the bottom. When a line of blocks has no gaps, it is complete and disappears. The maximum number of lines that can be completed simultaneously is 4, since at least one block is required per line. This can only be achieved with the 'I' tetromino: doing this is known as a 'tetris' [7]."

Table 1-1 *Split-plot design for this experiment*

Action game A	Respondent C					
	1			2		
	Time in natural rhythm B			B		
	MAP (Anytime between 9AM- 1:30PM)	DMA (Anytime between 1:30-3PM)	PLD (Anytime between 3- 4PM)	MAP (Anytime between 12-2PM)	DMA (Anytime between 2- 3:30PM)	PLD (Anytime between 3:30-4PM)
Not played N _p	(5)	(2)	(6)	(3)	(1)	(4)
Played P	(3)	(4)	(1)	(5)	(6)	(2)

The variables that are of interest in this study are summarized in the Tables Appendix-1 to 4.

To ensure that the level of ease/difficulty of all the multiplication problems is the same, a pre-test was conducted. The respondents were asked to solve different randomly generated three-digit numbers by another randomly generated three-digit numbers. They were asked suggestions to make all the multiplication problems equally “easy/challenging”. Their suggestions were enumerated in the Section 2. With the suggestions of respondents, another set of multiplication problems were produced. Another set of two randomly selected people were asked to solve the multiplication problems at the same time. The time for them to answer correctly each problem was recorded. These times were analyzed using a randomized complete block design to check if the difference between the sets of multiplication problem has no effect (Table 1-6). The numbers in parentheses are the run orders. The greatest α that would make the set of multiplication problems still not significant were used for analysis of this experiment.

Table 1-2 *Randomized complete block design*

Set/Type of Multiplication Problem D	Respondent C	
	1	2
I	(4)	(4)
II	(3)	(2)
III	(5)	(3)
IV	(1)	(6)
V	(2)	(5)
VI	(6)	(1)

1.3. Scope and Limitations

Though the experimenter wanted more replicates (respondents), only two were possible given the time constraints and the availability of the respondents. Aside from the limited time to accomplish the experiment, it was quite tricky to schedule the respondents as they too have limited time to participate in the experiment, being busy with other responsibilities in their academics, in their work, in their extra-curricular activities, etc.

The respondents were engineering students. Because of the simplicity of multiplying 3-digit by 3-digit numbers with respect to the capability of engineering students, the effect of the Circadian rhythm might not be apparent through measuring speed of solving the multiplication. Engineering students were chosen for this experiment because they are more accessible to the experimenter than other types of students, being that the experimenter is also an engineering student. Multiplication was still used because it is an everyday experience that does not require either extensive instruction or recall. With very simple instructions and apparent familiarity, it is guaranteed that the respondent would execute the study properly.

The electronic handheld action game used in this experiment was Tetris. It was used because of its popularity and simplicity. Most students have played the game. However, the game might be too simple to really induce an adrenaline rush necessary to increase the alertness of the respondents.

It was assumed that the speed of multiplying implies mental alertness.

2. Data and Analysis

The numbers the respondents were asked to multiply in the pre-test were:

- 182 x 202 • 927 x 342
- 175 x 636 • 995 x 897
- 984 x 633 • 383 x 819

According to the respondents, these numbers were not equally easy/challenging. For instance, it is easier to multiply 182 by 202 than to multiply 995 by 897. The first pair was relatively easy to multiply because 2 had been repeated thrice, 0 existed, and multiplying 1 by 2 was easy. The second pair was relatively difficult to multiply because of the difficulty of multiplying 7 by 9 and 8 by 9. The respondents suggested that there should be no zero in any number, and a digit could not be repeated once it had been used in a pair. The new pairs of numbers were:

- I: 437 x 861 • II: 632 x 589
- III: 876 x 324 • IV: 457 x 326
- V: 514 x 829 • VI: 614 x 328

The results of the randomized complete block design (Table 1-2) are presented in the table below (Table 2-1). The ANOVA of Table 2-1 is presented in Table 2-2.

Table 2-1 *Results of the randomized complete block design experiment presented in Table 1-2*

Set of multiplication problem D	Respondent C	
	1	2
I	50.720	57.740
II	69.330	51.550
III	51.190	44.310
IV	56.690	50.600
V	51.910	45.920
VI	56.970	39.200

Table 2-2 ANOVA of Table 2-1

Source of Variation	SS	df	MS	F	f ($\alpha=0.44$)	P	Conclusion
Set of multiplication problem D	243.26	5	48.65	1.14	1.15	0.56	
Respondent C (Blocks)	187.94	1	187.94				
Error	212.80	5	42.56				
Total	644.00	11					

From Table 2-2, it is clear that the sets/types of multiplication problem had no effect to the time of the respondents to answer them correctly until α becomes greater than 0.44. Thus, $\alpha = 0.44$ was used in the split-plot design (Table 1-1).

The results of the split-plot design (Table 1-1) are presented in Table 2-3. The ANOVA of Table 2-3 is presented in Table 2-4.

Table 2-3 Results of the split-plot design experiment presented in Table 1-1

Action game	Respondent C					
	1			2		
	Time in natural rhythm B			B		
	map	dma	Pld	map	dma	Pld
Np	42.12	50.55	52.26	56.02	41.87	42.85
P	42.21	37.30	38.30	42.18	49.05	60.34

Table 2-4 ANOVA of Table 2-3

Source of Variation	SS	df	MS	F	f ($\alpha=0.44$)	P	Conclusion
Respondent C	72.87	1	72.87				
Time in natural rhythm B	30.37	2	15.18	0.25	1.27	0.20	
BC (whole plot error)	120.70	2	60.35				
Action game A	22.11	1	22.11	0.25	0.91	0.33	
AC	120.02	1	120.02				
AB	37.48	2	18.74	0.21	1.27	0.17	
ABC (subplot error)	176.88	2	88.44				
Total	580.42	11					

At $\alpha=0.44$, the time it takes to multiply 3-digit by 3-digit numbers are neither affected by the time in the respondents natural rhythm nor whether he/she played the action game or

not.

The hypothesis test to check if playing the action game increases alertness to counter PLD is summarized in Figure 2-1.

Table 2-5 *Difference between Np and P during PLD (mean=-1.765, std=22.2385)*

Respondent C	Np	P	Difference (Np-P)
1	52.26	38.30	13.96
2	42.85	60.34	-17.49

Figure 2-1 *Hypothesis test to determine if A counters PLD*

1. $H_0: \mu_1 - \mu_2 = 0$
2. $H_1: \mu_1 - \mu_2 \neq 0$
3. $\alpha = 0.44$
4. Critical region: $t < -1.21, t > 1.21$
5. Test statistic: $t = \frac{-1.765}{22.2385 / \sqrt{2}} = -0.1121$
6. Conclusion: Do not reject $H_0: \mu_1 - \mu_2 = 0$

The sample size and the power of the test cannot be computed because σ^2 is not estimable [8].

3. Results and Discussion

The experiment revealed that on multiplying 3-digit by 3-digit numbers, the respondents were neither affected by the time in their natural rhythm nor whether they played the action game or not. The variation of the time to answer correctly the multiplication problem is mainly due to the difference between the respondents.

The hypothesis test in Figure 2-1 revealed that playing the action game did not increase the time to answer correctly the multiplication problem during PLD.

A visual inspection of the normal probability plots (Figure Appendix-5 and 8), residuals of block 1 versus order of data (Figure Appendix-6 and 9), and residuals of block 2 versus order of data (Figure Appendix-7 and 10) from Table 2-1, and from Table 2-3 revealed that the normality and independence assumptions were satisfied with the randomized complete block design (Table 2-1) and with split-plot design (Table 2-3).

The speed in multiplying 3-digit by 3-digit numbers correctly might not be a good indicator of mental alertness, especially for engineering students. Multiplication might be too

familiar that a person can multiply efficiently without being affected by mental alertness. This might be so with people who solve more complicated mathematical problems frequently.

Tetris might be too familiar and simple to induce the anticipated adrenaline rush to influence mental.

4. Conclusions and Recommendations

From other researches and experiments (see section 1), it was established that mental alertness is influenced by the time in the natural rhythm. The speed of multiplication of 3-digit by 3-digit numbers was not an appropriate measure of mental alertness, especially so if the respondents were used to solving more complicated mathematical problems (e.g. engineering students).

It was also established that action games induce adrenaline rush (see section 1), and adrenaline rush increases mental alertness. Simple action games such as Tetris however might not induce the adrenaline rush necessary to increase mental alertness.

This experiment could be improved by finding an appropriate response to implicate mental alertness, and this response should be designed for the target respondents. The response should be not too simple to what the target respondents are usually exposed to, but should not be too complicated that they would be confused on how they should participate in the experiment. The action games could be made a little more complicated than Tetris however the game should be familiar to the target respondents such that they would not find it confusing, however not too familiar that playing the game does not excite them.

Appendix

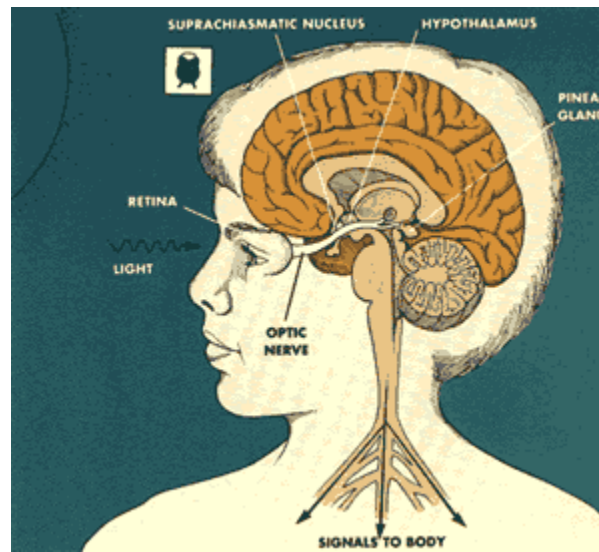


Figure Appendix-1 *Location of SCN* [3]

Do you consider yourself a morning person or an evening person?

- A. Evening
- B. More evening than morning
- C. Can't tell
- D. More morning than evening
- E. Morning

At what time of day do you feel at your best?

- A. 5am - 9am
- B. 9am - 11am
- C. 11am - 5pm
- D. 5pm - 10pm
- E. 10pm - 1am

Considering only your own "feeling best" rhythm, if you were entirely free to plan your day - at what time would you go to bed?

- A. 8pm - 9pm
- B. 9pm - 10.15pm
- C. 9pm - 10.15pm
- D. 12.30am - 1.45am
- E. 1.45am - 3am

Considering only your own "feeling best" rhythm, if you were entirely free to plan your day - at what time would you get up?

- A. 5.00am - 6.30am
- B. 6.30am - 7.45am
- C. 7.45am - 9.45am
- D. 9.45am - 11.00am
- E. 11.00am - Midday

Figure Appendix-2 *Questionnaire from the BBC's website*

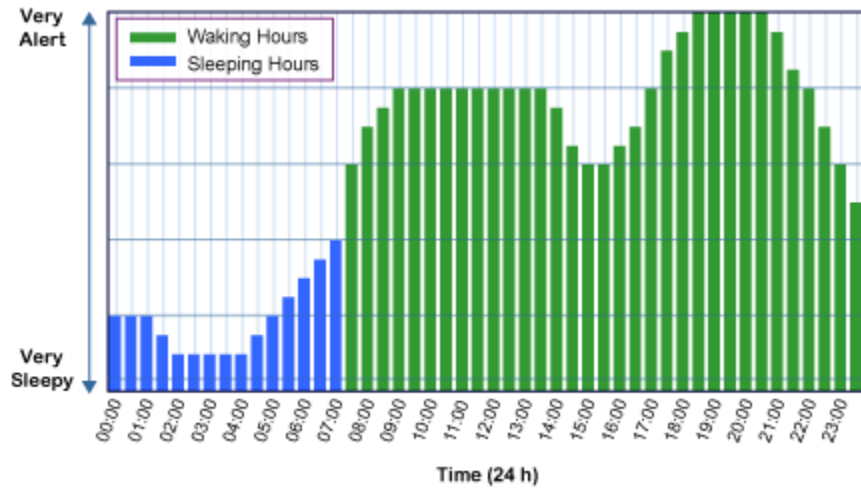


Figure Appendix-3 Result of Daily Rhythm Test of Respondent 1

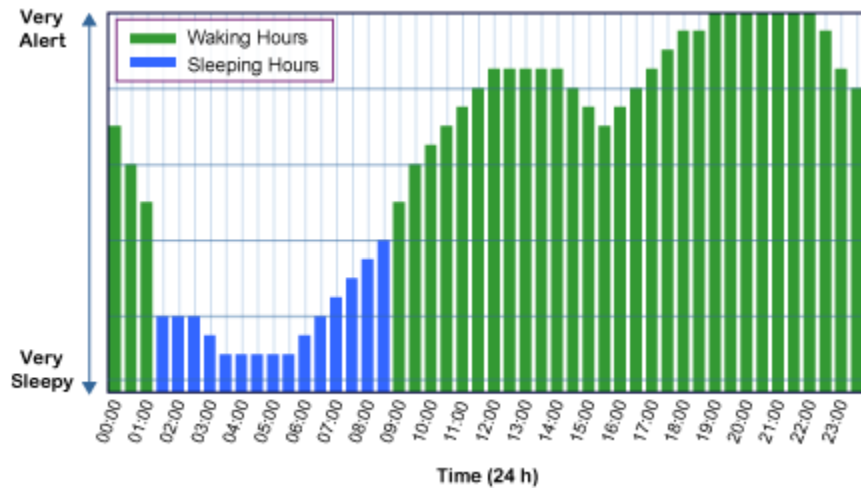


Figure Appendix-4 Result of Daily Rhythm Test of Respondent 2

Table Appendix-1 Response Variable

Response variable (units)	Normal operating level and range	Measurement precision, accuracy How known?	Relationship of response variable to objective
Time to answer correctly (seconds)	0 to 120	0.01 second (feature of stopwatch)	Time to answer correctly implies degree of alertness

Table Appendix-2 Control Variables

Control variables (units)	Normal level and range	Measurement precision and setting error How known?	Proposed settings, based on predicted effects	Predicted effects
A (Categorical)	P or Np	N/A	P, Np	P decreases <i>Time to answer correctly</i>
B (Categorical)	MAP, DMA, PLD	N/A	MAP, DMA, PLD	As <i>time in natural rhythm</i> approaches PLD, <i>Time to answer correctly</i> increases

Table Appendix-3 Factors “Held constant”

Factor (units)	Desired experimental level and allowable range	Measurement precision How known?	How to control (in experiment)	Anticipated effects
Coffee (Categorical)	None taken	N/A	Request respondent to not drink coffee	None
Ice-cold juice (Categorical)	None taken	N/A	Request respondent to not drink ice-cold juice	None
Brisk walk (Categorical)	None taken	N/A	Request respondent to not walk briskly before the test	None
Nap (Categorical)	None taken	N/A	Request respondent to not take a nap before the test	None

Table Appendix-4 Nuisance Factors

Nuisance factor (unit)	Measurement precision How known?	Strategy	Anticipated effects
C (person)	N/A	Blocking	None
Set/type of multiplication problem D (problem)	N/A	Ensure that type of multiplication problem has no effect to the <i>Time to answer correctly</i> (i.e. ensure that the level of ease/difficulty of all the multiplication problems is the same)	None

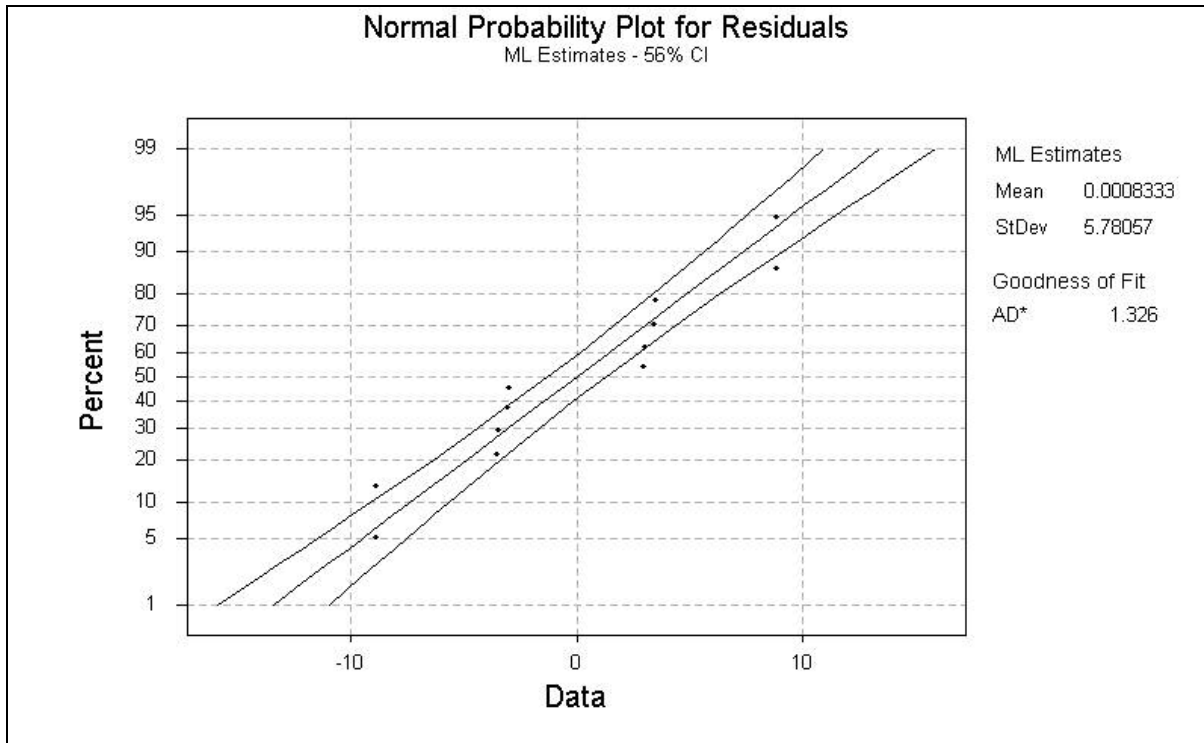


Figure Appendix-5 Normal probability plot from Table 2-1

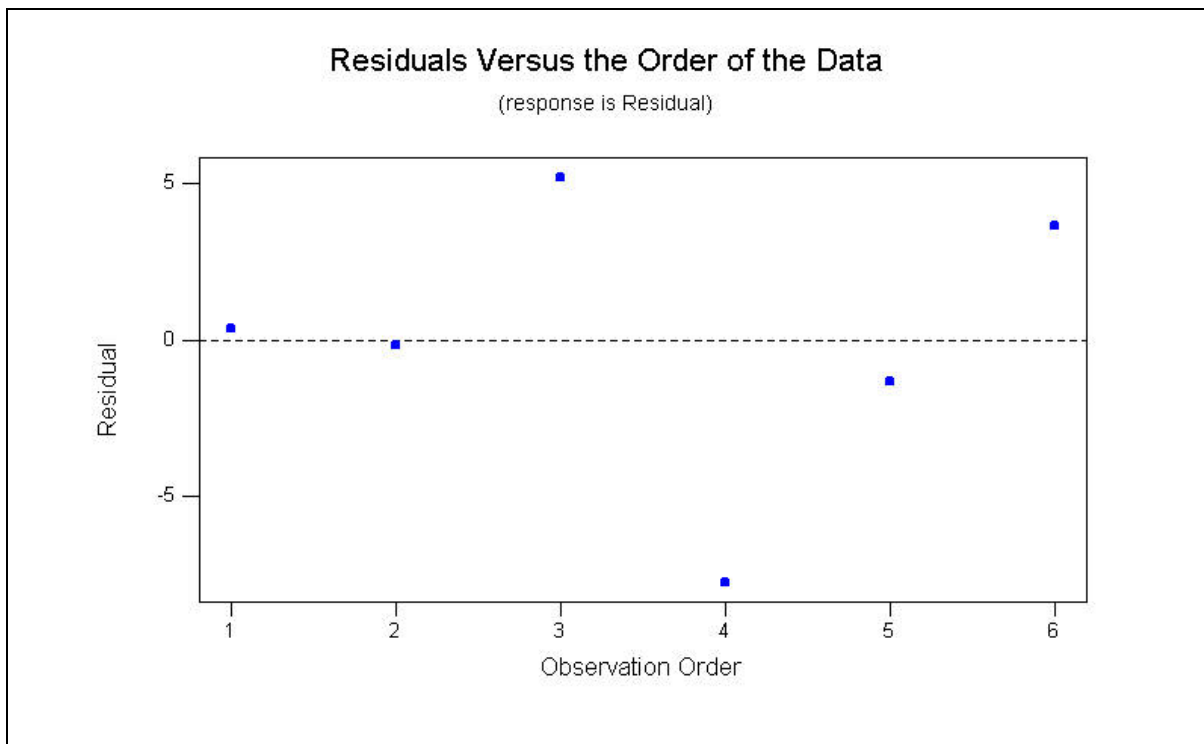


Figure Appendix-6 Residuals of Block 1 vs. Observation Order from Table 2-1

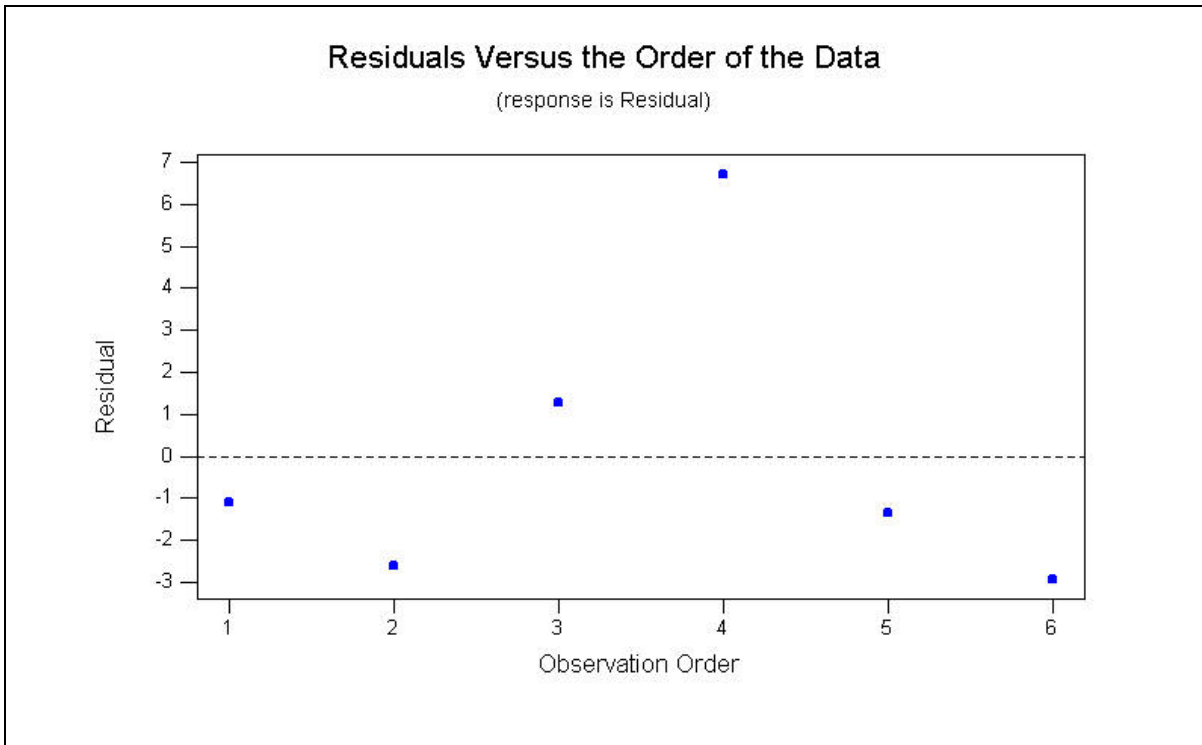


Figure Appendix-7 Residuals of Block 2 vs. Observation Order from Table 2-1

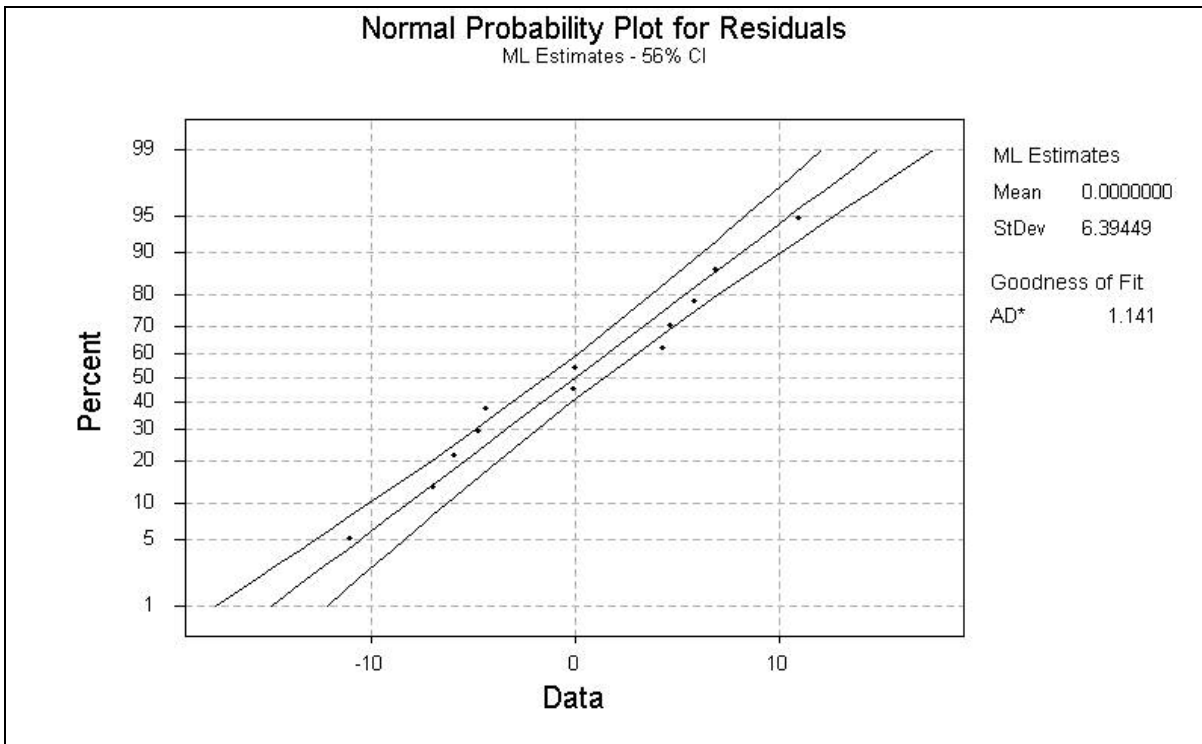


Figure Appendix-8 Normal Probability Plot of Table 2-3

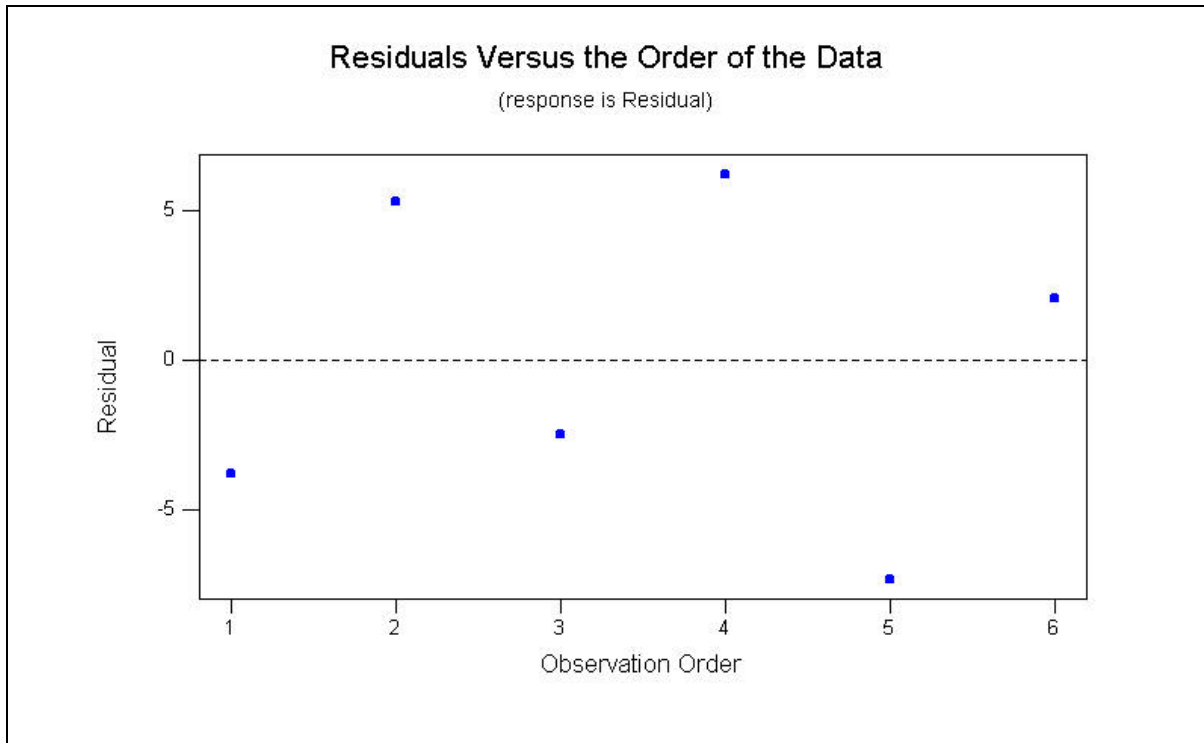


Figure Appendix-9 Residuals of Block 1 vs. Observation Order from Table 2-3

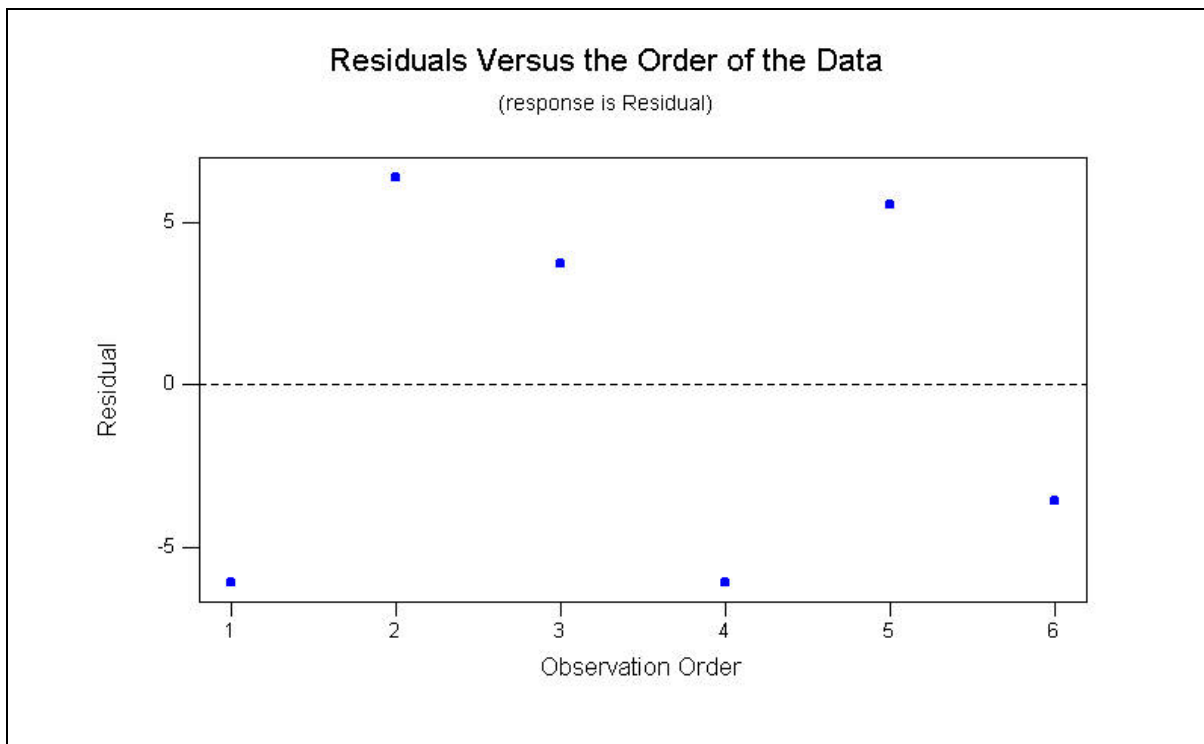


Figure Appendix-10 Residuals of Block 2 vs. Observation Order from Table 2-3

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