Study Report On Coffee And Napping: Interactive Effect On Memory

Lingye Kong, Yufan Zhao, Jingxian Shu

Introduction

Daytime naps have been long recognized as a beneficial way for memory consolidation. One study that was conducted by Cousins et al. (2018) found that a 60-90 minute nap significantly enhances long-term memory in a memory game test and outperforms “cramming” strategies in which participants memorize shortly before the game starts. Similarly, a 2021 systematic review conducted by Ullah et al. (2021) shows that an average 55-minute nap will modestly improve the general cognitive function, especially in working memory, compared to no-nap conditions.

On the other hand, another factor that has been consistently tested is the influence of caffeine intake, as it has been credited with improving attention and alertness. However, the research into its effect on memory is mixed. In Lin et al. (2022)’s study on caffeine test, they have reached the conclusion that caffeine increased the working memory-related regions measured through fMRI but did not actually improve task performance. While some studies suggest caffeine can benefit certain memory tasks, Ullah et al. (2021) conclude that caffeine’s impact on working memory is inconsistent.

Despite the plentifulness of research, the effects of both napping and caffeine on short-term memory remain ambiguous. Given these mixed findings, our study uses a 2x2 factorial design in an attempt to explore the combined and individual effects of a 30-minute nap and caffeine ingestion on short-term memory performance. Our hypothesis is that there will be some kind of interaction between these two variables. Participants are sampled from three different island populations from the simulation “Island” project. By analyzing both the main effect and the interaction effect, our goal is to provide clear insight into how everyday interventions influence short-term memory.

Design of the experiment

To get to our research question, since we are focusing on the effect of caffeine and nap on memory, we selected two treatment factors that can be used in the Island website: one is caffeine, and the other is nap. Each of them has two levels. A 2 by 2 factorial design was used in the paper as it will demonstrate the individual main effect of the factor as well as its interaction effects. Therefore, we can assign all the participants into four groups with different treatment combinations: A (Caffeine + Nap), B (Caffeine + No Nap), C (Decaf + Nap), D (Decaf + No Nap). By using R’s sample function to determine the necessary sample size for detecting a medium effect, we conducted a balanced one-way ANOVA power calculation using:

Effect size = 0.28
Alpha level = 0.05
Desired power: 0.8
Number of groups = 4

```
> library(pwr)

> pwr.anova.test(k = 4, f = 0.28, sig.level = 0.05, power = 0.
8)

     Balanced one-way analysis of variance power calculation

              k = 4
              n = 35.75789
              f = 0.28
      sig.level = 0.05
          power = 0.8

NOTE: n is number in each group
```

The power analysis indicated that approximately 36 participants per group (n = 35.76) are needed to detect a statistically significant effect under these assumptions. In our experiment, we took 36 participants per group (144 total), meeting the minimum requirement suggested by the power analysis. This suggests that our experiment is sufficient to detect medium-sized effects of 0.28.

To meet the required sample size of 144 participants with 36 per treatment group, we recruited subjects from three separate islands, selecting 48 participants from each island using stratified sampling by location. After pooling all 144 participants, we randomly assigned them to four treatment groups with 36 participants per group.

Within groups related to caffeine, we gave each participant 250 ml of regular coffee or decaf caffeine, depending on the group they were in, and we gave participants a 30-minute nap or no nap at all in the nap-related group. To measure the impact on memory, we chose our response variable to be the time to complete a memory game; a shorter period for each participant to complete the game indicates a better memory.

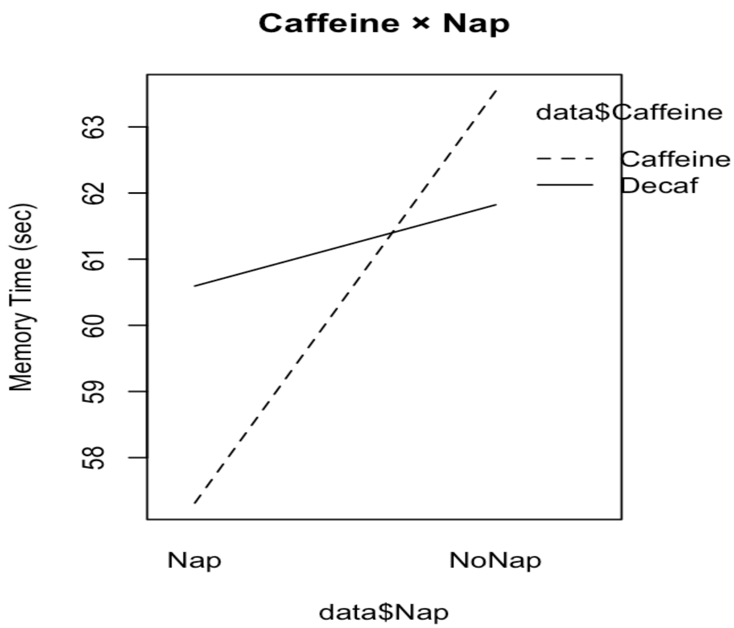
Since we decided to add the blocking after data collection, instead of redoing all the data collection again to meet the balanced blocking design, we chose to do the unbalanced blocking design, meaning randomization is performed without regard to age, and age information was done afterward to define the age block for analysis.

Results and interpretation

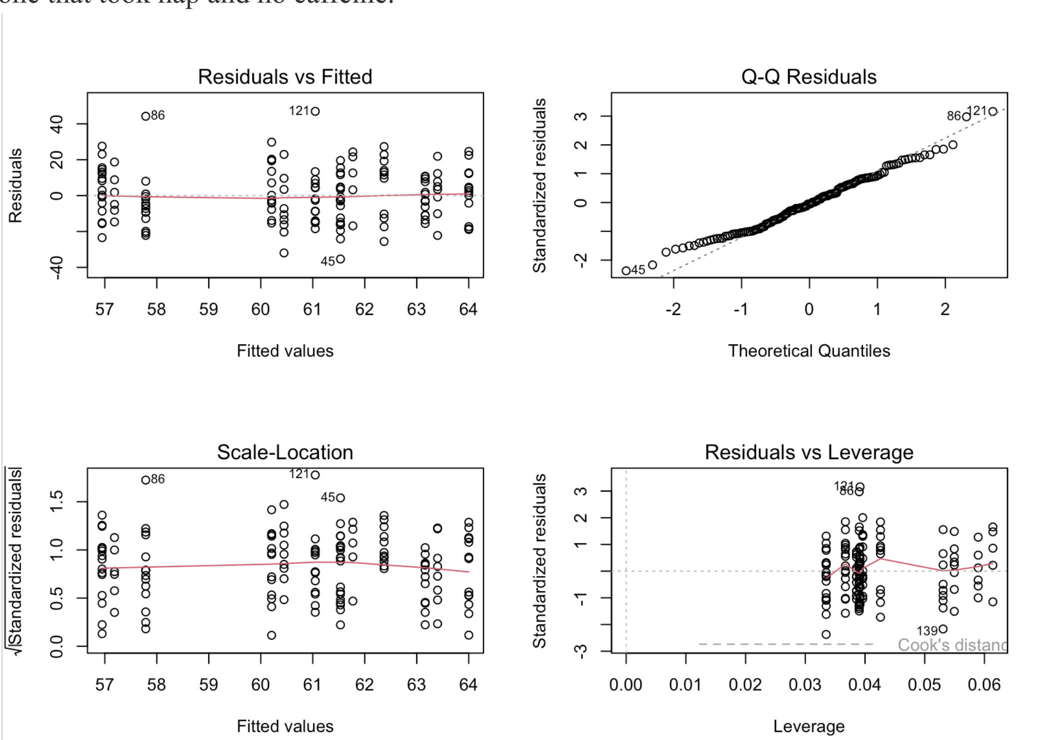
```
> Anova(model, type = "III")
Anova Table (Type III tests)

Response: MemoryTime
             Sum Sq  Df  F value  Pr(>F)
(Intercept)   88327   1 384.5782 < 2e-16 ***
Caffeine        190   1   0.8278 0.36449
Nap             693   1   3.0179 0.08458 .
Block            21   2   0.0447 0.95629
Caffeine:Nap    211   1   0.9192 0.33936
Residuals     31695 138
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

The ANOVA results using Type III sum of squares revealed that none of the treatment effects reached statistical significance at the 0.05 level. Caffeine (F(1,138) = 0.83, p = 0.364), nap (F(1,138) = 3.02, p = 0.085), and their interaction (F(1,138) = 0.92, p = 0.339) are not statistically significant. The blocking factor, age group, also had no significant effect (F(2,138) = 0.044, p = 0.956), indicating that age block did not account for meaningful variability in memory performance. Although napping showed a marginally low p-value, it still cannot be considered significant, so we cannot conclude that either caffeine, napping, or their combination had a statistically significant impact on short-term memory time. To further analyze the data, the average performance of the four groups is also calculated. Among the four groups, the group that took caffeine and a nap scored the best with 57.31 seconds. Even though this shows some improvement in the memory performance, the anova table has suggested that the change is not enough to prove that it is statistically significant.

```
> aggregate(MemoryTime ~ Caffeine + Nap, data = data, mean)
  Caffeine   Nap MemoryTime
1 Caffeine   Nap   57.31389
2    Decaf   Nap   60.59444
3 Caffeine NoNap   63.54167
4    Decaf NoNap   61.82222
```



Additionally, the interaction plot also came to a similar result that participants who napped while taking caffeine drinks appeared to perform slightly better on average. The second best performing group is the one that took nap and no caffeine.



The Residual vs Fitted plot and Scale-location plot shows no clear pattern and the points are around the x = 0 line, the Q-Q plot indicates that the standardized residuals are approximately normally distributed, indicating that the assumption of normality and homogeneity of variance were reasonably met, and no highly influential data points were shown based on the Residuals vs Leverage plot. These plots guarantee the accuracy of our results from the ANOVA table.

Discussion

Our study tested the hypothesis that caffeine intake and daytime nap would have an interactive effect to enhance short-term memory performance. While prior research conducted by Cousins et al. (2018) and Ullah et al. (2021) has all demonstrated significant improvements in long-term memory boost following naps, our results showed no significant main effects or interaction between caffeine and nap for short-term recall. Our results are therefore different from these research results and the original hypothesis that we believe in.

A broader study by Mednick et al. (2008) directly compares caffeine (200 ml), a 60-minute nap, and a placebo on perceptual memory tasks has found that there is no clear superiority of caffeine or naps over the placebo effect. Our study closely resembles Mednick's data, in which our main effect for caffeine intake and nap also does not show any significance. One possible explanation could be that short-term recall is less responsive to the intervention compared to tasks that require long-term memory or procedural memory. Another potential reason is that the baseline performance for each participant might already be high, which leaves limited room for improvement in the performance of the game.

However, there are certain limitations when the research is being conducted. After collecting the stratified sample from the island, we have unintentionally conducted an unbalanced block design where the block size for each group is unbalanced. Other confounding variables might influence the result of the study, such as prior caffeine use, sleep quality, and experimental environment.

Despite these limitations, our findings still have practical implications. Taking coffee or a nap or a combination of the two for an individual seeking short-term improvement will be useless and should be considered with care. In future studies, the researcher should refine their method of testing to better understand the effect of these two interventions.

Citation

Cousins, J. N., Wong, K. F., Raghunath, B. L., Look, C., & Chee, M. W. (n.d.).Long-term memory benefits of a daytime nap compared with cramming | sleep | Oxford academic. https://academic.oup.com/sleep/article/42/1/zsy207/5146032

Dutheil, F., Danini, B., Bagheri, R., Fantini, M. L., Pereira, B., Moustafa, F., Trousselard, M., & Navel, V. (2021, September 28). *Effects of a short daytime nap on cognitive performance: A systematic review and meta-analysis*. International journal of environmental research and public health. https://pmc.ncbi.nlm.nih.gov/articles/PMC8507757

Lin, Y.-S., Weibel, J., Landolt, H.-P., Santini, F., Slawik, H., Borgwardt, S., Cabochon, C., & Reicher, C. F. (n.d.). *Brain activity during a working memory task after daily caffeine intake and caffeine withdrawal: A randomized double-blind placebo-controlled trial*. Scientific reports. https://pubmed.ncbi.nlm.nih.gov/36653409/

Mednick, S. C., Cai, D. J., Kanady, J., & Drummond, S. P. A. (2008, May 8). *Comparing the benefits of caffeine, naps and placebo on verbal, motor and Perceptual Memory*. Behavioral Brain Research. https://www.sciencedirect.com/science/article/pii/S0166432808002416

Appendix

Power Analysis:

```r
library(pwr)
pwr.anova.test(k = 4, f = 0.28, sig.level = 0.05, power = 0.8)







set.seed(123)

island <- rep(1:3, each = 48)
person <- rep(1:48, times = 3)
all_people <- data.frame(Island = island, Person = person)

shuffled <- all_people[sample(nrow(all_people)), ]
shuffled$Group <- rep(1:4, each = 36)
split_by_group <- split(shuffled[, c("Island", "Person")], shuffled$Group)

for (i in 1:4) {
  cat(paste0("\n--- Group ", i, " ---\n"))
  print(split_by_group[[i]])
}
```

Data Collection:

--- Group 1 ---

	Island	Person
14	1	14
50	2	2
118	3	22
43	1	43
144	3	48
142	3	46
90	2	42
91	2	43
137	3	41
92	2	44
99	3	3
72	2	24
26	1	26
7	1	7
78	2	30
81	2	33
141	3	45
103	3	7
117	3	21
76	2	28
15	1	15
32	1	32
106	3	10
109	3	13
131	3	35
9	1	9
41	1	41
74	2	26
23	1	23
27	1	27
60	2	12
53	2	5
120	3	24
113	3	17
115	3	19
96	2	48

--- Group 2 ---

	Island	Person
38	1	38
89	2	41
34	1	34
93	2	45
69	2	21
133	3	37
125	3	29
63	2	15
13	1	13
82	2	34
97	3	1
136	3	40
25	1	25
108	3	12
21	1	21
79	2	31
139	3	43
47	1	47
138	3	42
114	3	18
16	1	16
6	1	6
127	3	31
39	1	39
31	1	31
129	3	33
143	3	47
122	3	26
4	1	4
100	3	4
104	3	8
121	3	25
52	2	4
22	1	22
123	3	27
77	2	29

--- Group 3 ---

	Island	Person
35	1	35
40	1	40
30	1	30
12	1	12
84	2	36
70	2	22
64	2	16
140	3	44
29	1	29
126	3	30
112	3	16
3	1	3
116	3	20
54	2	6
58	2	10
124	3	28
94	2	46
37	1	37
8	1	8
51	2	3
10	1	10
134	3	38
42	1	42
44	1	44
83	2	35
102	3	6
75	2	27
130	3	34
20	1	20
17	1	17
86	2	38
71	2	23
67	2	19
57	2	9
24	1	24
107	3	11

--- Group 4 ---

	Island	Person
62	2	14
66	2	18
85	2	37
55	2	7
132	3	36
87	2	39
65	2	17
36	1	36
110	3	14
98	3	2
5	1	5
68	2	20
88	2	40
56	2	8
11	1	11
80	2	32
45	1	45
135	3	39
111	3	15
119	3	23
18	1	18
2	1	2
105	3	9
61	2	13
59	2	11
33	1	33
95	2	47
46	1	46
1	1	1
73	2	25
28	1	28
128	3	32
49	2	1
48	1	48
101	3	5
19	1	19