The Effect of Pre-Bedtime Habits on Sleep Quality Preanalysis Plan

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Introduction

Older generations love to assign the cause of virtually any ailment to the increased usage of mobile phones and other electronic devices in today's digital age. This extends to the realm of sleep, where it is commonly believed that the use of screens before bed negatively impacts sleep. Past research suggest that blue light exposure from devices decrease sleep quality, sleep duration, and sleep efficacy (Silvani, Werder, and Perret 2022). In contrast, reading a physical book before bed is thought to promote better sleep (Finucane 2021).

This randomized controlled trial aims to assess how different pre-bedtime habits affect sleep quality and sleep efficacy, as measured by the Sleep Cycle app on an Apple Watch. Specifically, the experiment compares the sleep quality scores and sleep efficacy between nights when using a phone for 20 minutes before bed and nights when reading a physical book for 20 minutes before bed. The hypothesis is that reading a book before bed will result in higher sleep quality scores and better sleep efficacy compared to using a phone.

Experimental Design

The experiment considers the effects of two pre-bedtime habits on sleep quality and sleep efficacy. Sleep quality is measured by the Sleep Cycle app on an Apple Watch, which provides a sleep quality score ranging from 0 to 100. The app produces the personalized aggregate score based on four measurements: 1) the amount of time spent in bed, 2) the amount of time spent in deep asleep, 3) the frequency of motion and intensity for each movement, and 4) the amount of times the app registered the user as fully awake. Sleep efficacy is defined as the percentage of time spent asleep while in bed. Time spent sleeping is similarly determined by the Sleep Cycle app through sound and motion detection.

The following hypotheses regarding sleep-related outcomes are tested:

H1: (Sleep Quality) Reading a physical book before bed results in higher sleep quality scores compared to using a phone.

H2: (Sleep Efficacy) Reading a physical book before bed results in better sleep efficacy compared to using a phone.

Context and Population

We test our theory by conducting an experiment with a sample of one participant over the course of three weeks, with each night serving as a unit of analysis. The sole participant is a 21-year-old female college student, chosen for convenience. The participant has no known sleep disorders.

Intervention

Each night across the duration of the experiment will be randomly assigned to either the treatment group or the control group. The treatment condition consists of reading a physical book for 20 minutes before bed, while the control condition consists of using a phone for 20 minutes before bed.

Random Assignment

Each night is randomly assigned to the treatment or control using a simple random assignment procedure. The random assignment is conducted using the `sample()` function in R, which randomly assigns the treatment or control group with equal probability—akin to a coin flip. By randomizing the treatment conditions, we ensure that all potential confounders that are not accounted for are equally distributed between the treatment and control groups.

Simple randomization is chosen over complete randomization to ensure blinding. Given that complete randomization balances the sizes of the treatment and control groups, the participant would be able to deduce the treatment condition for nights toward the end of the study duration based on the assignments of the previous nights.

The condition for each night is determined before the participant goes to bed to avoid violations of excludability. In other words, the timing of the assignment ensures that the participant does not alter other behaviors that could affect sleep.

Implementation Procedure

The participant is instructed to wear an Apple Watch for each night of the experiment. The Sleep Cycle app is installed on the Apple Watch to collect data on sleep quality and sleep efficacy. Devices are charged during the day to ensure that the battery does not run out during the night.

If assigned the treatment condition, the participant reads a physical book of their choice in their dorm room. If assigned the control condition, the participant uses their phone for 20 minutes before bed, which mimics the behavior of the participant's typical nighttime routine.

In the morning, the participant records the sleep efficacy and sleep quality scores as reported by the Sleep Cycle app. The app outputs the sleep quality scores on a scale of 0 to 100, with higher scores indicating better sleep quality. The app also gives the total time spent in bed and the total time spent asleep, which are used to calculate sleep efficacy.

Outcome Measurement

The complete schedule of fake data is shown in the tables below.

Table 1: Sleep Quality Scores

Night	Sleep Quality Control	Sleep Quality Treatment	Treatment Effect	Treatment Assignment	Observed Sleep Quality
1	64.39524	74.32176	9.926519	0	64.39524
2	67.69823	82.82025	15.122026	1	82.82025
3	85.58708	74.73996	-10.847128	1	74.73996
4	70.70508	77.71109	7.006004	1	77.71109
5	71.29288	78.74961	7.456730	0	71.29288
6	87.15065	68.13307	-19.017583	1	68.13307
7	74.60916	93.37787	18.768708	0	74.60916
8	57.34939	86.53373	29.184344	0	57.34939
9	63.13147	73.61863	10.487159	1	73.61863
10	65.54338	97.53815	31.994769	0	65.54338
11	82.24082	89.26464	7.023824	1	89.26464
12	73.59814	82.04929	8.451147	1	82.04929
13	74.00771	93.95126	19.943542	1	93.95126
14	71.10683	93.78133	22.674508	1	93.78133
15	64.44159	93.21581	28.774222	0	64.44159
16	87.86913	91.88640	4.017271	0	87.86913
17	74.97850	90.53918	15.560672	0	74.97850
18	50.33383	84.38088	34.047055	1	84.38088
19	77.01356	81.94037	4.926814	1	81.94037
20	65.27209	81.19529	15.923204	1	81.19529

Table 2: Sleep Efficacy Scores

Night	Sleep Efficacy Control	Sleep Efficacy Treatment	Treatment Effect	Treatment Assignment	Observed Sleep Efficacy

1	86.52647	94.89820	8.3717323	0	86.52647
2	88.96041	90.48838	1.5279691	1	90.48838
3	83.67302	91.33396	7.6609448	1	91.33396
4	100.84478	87.90712	-12.9376567	1	87.90712
5	96.03981	87.64104	-8.3987661	0	96.03981
6	84.38446	94.51764	10.1331861	1	94.51764
7	87.98558	95.24105	7.2554731	0	87.98558
8	87.66672	93.26502	5.5982979	0	87.66672
9	93.89983	97.61134	3.7115117	1	97.61134
10	89.58315	103.25042	13.6672688	0	89.58315
11	91.26659	90.54484	-0.7217484	1	90.54484
12	89.85727	81.45416	-8.4031106	1	81.45416
13	89.78565	98.02869	8.2430449	1	98.02869
14	96.84301	89.45400	-7.3890152	1	89.45400
15	88.87115	89.55996	0.6888118	0	88.87115
16	97.58235	98.12786	0.5455038	0	97.58235
17	82.25624	91.57613	9.3198990	0	82.25624
18	92.92307	86.89641	-6.0266573	1	86.89641
19	90.61927	93.90652	3.2872462	1	93.90652
20	91.07971	92.30554	1.2258353	1	92.30554

Results

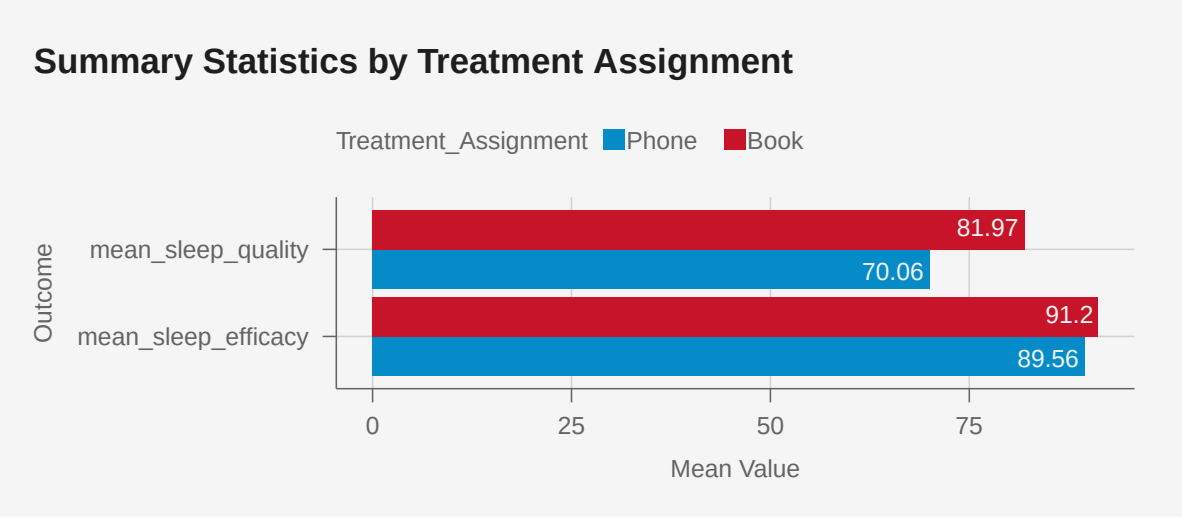
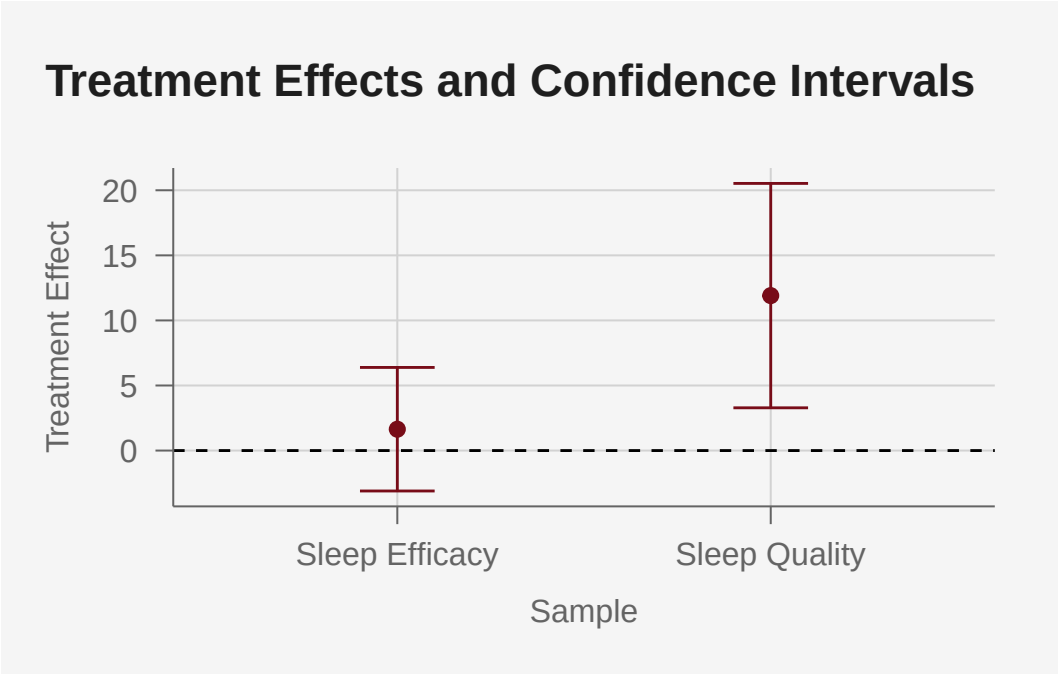


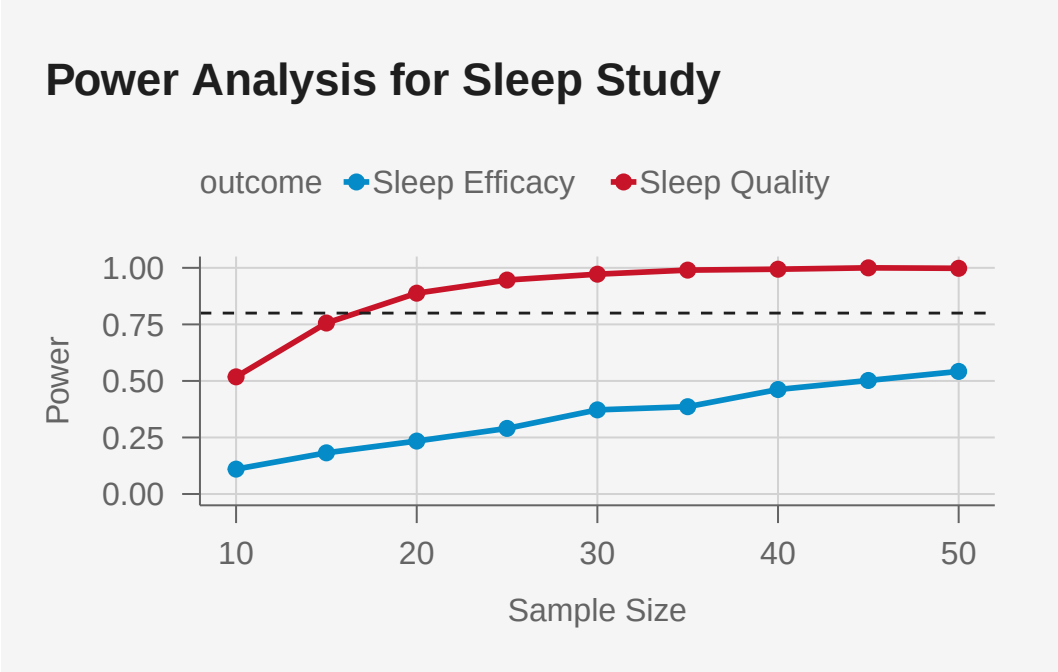
Table 3: Summary Statistics and P-Values

Outcome	Book	Phone	p_Value
Average Sleep Quality	81.96550	70.05991	0.0105015
Average Sleep Efficacy	91.20405	89.56393	0.4715226



For our sample of fake data, the average sleep quality score was approximately 70.06 for nights when the participant used a phone before bed and 81.97 for nights when the participant read a book before bed. This yielded a statistically significant treatment effect of 11.91 in favor of reading a book ($p = 0.01$). However, the results for sleep efficacy were not statistically significant, with an average sleep efficacy of 89.56 for phone nights and 91.20 for book nights ($p = 0.47$).

Power Calculations

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Required sample size for 80% power (Sleep Quality): 20
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Required sample size for 80% power (Sleep Efficacy): 85
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The power analysis indicates that the experiment has 88.9% power to detect a statistically significant treatment effect of 15 on sleep quality and 26.3% power to detect a treatment effect of 3 on sleep efficacy. The required sample size for 80% power is 20 nights for sleep quality and 90 nights for sleep efficacy. So while the experiment is adequately powered to detect differences in sleep quality, it is underpowered to detect differences in sleep efficacy if the effect size is as small as 3. Due to the circumstances of the experiment, it is not feasible to increase the sample size to achieve the desired power for sleep efficacy.

Conclusion

The fake data analysis suggests that reading a book before bed leads to significantly higher sleep quality scores compared to using a phone. However, the results for sleep efficacy were not statistically significant. Further analysis with more nights should be conducted to confirm these findings, particularly for sleep efficacy.