Effect of Exposure to Different Colors on Tiredness and Anxiety

Hyunjoon Rhee, Jinho Lee

Introduction

Colors are known to have different kinds of effects on humans' psychological condition. For example, perceiving color red could bring out passion, energy, and aggression, whereas perceiving color blue could induce tranquility, coolness and more. Due to such traits, psychological treatments with colors are widely used around the world. Chromotherapy, also known as, color therapy is one the best examples of the usage, which is known as a treatment that brings balance to improve one's mood. Considering this color therapy, we got interested in how effective these color treatments are on one's tiredness or anxiety level.

We wanted to conduct an experiment to study the relationship between samples' exposure to different colors and level of tiredness or anxiety. In order to check the validity of color therapy, we handed out online surveys using different color effects on the background of the survey, to see how these colors might have an impact on the result of the survey.

After collecting the data, we analyzed the data using the best fit model for our data, and the model assumption to proceed with the analysis. Further analysis such as ANOVA was conducted to find out the relationship between color and psychological status.

Experimental Design

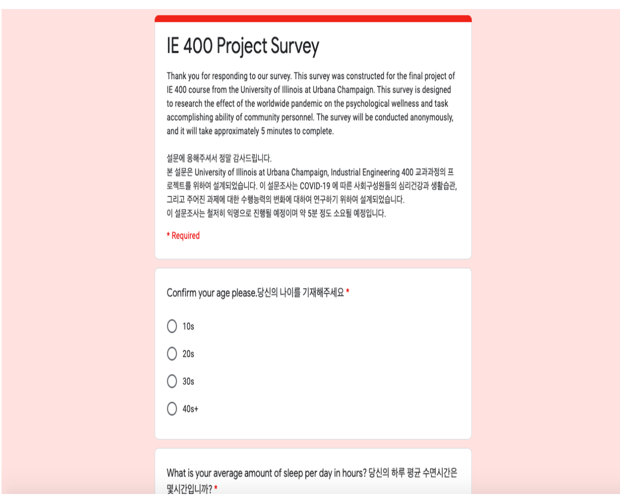
In the experimental idea, we have decided to consider three factors: age group, time the survey was taken, and color of the survey. Before proceeding to the major experiment, we defined our blocks and treatments.

In order to determine the blocking factor, note that our experimental unit is a person responding to the survey, and the response variable is a level of tiredness and anxiety. The purpose of blocking factors is to divide the experimental units in homogenous groups and to make the difference between such groups as great as possible, we set the age of the person taking the survey and the time that survey was taken blocking factors. More detailed reasoning is the following:

- Age - Age is an important characteristic of the experimental unit when self-diagnosing one's tiredness and anxiety; e.g. teenagers are most likely to have high levels of anxiety from school and college admissions. Since we are studying the relationship between the color exposure and tiredness level, we do not want the experimental units' age to affect our result. Therefore, we set the age as a blocking variable.
- Time - The time when an experimental unit takes the survey would also affect one's psychological status. Again, we are mainly interested in the effect of exposure to different colors. Therefore, we set time to be a blocking variable.

We created an online survey with 10 questions, among which only 2 questions are related to one's anxiety and tiredness. In order to differentiate the color that they are exposed to, we splitted the surveys into 4 groups using different background/theme colors see figure 3 for the survey examples. In order to keep the purpose of the survey confidential, we told our experimental units that the survey is designed to study the relationship between the COVID-19 pandemic and people's task accomplishing ability. The three relevant questions were:

1. Do you often feel tired nowadays?
2. Do you feel anxious before starting a new task/project?
3. How lively do you think this person's emotion is? (see figure 2)



IE 400 Project Survey

Thank you for responding to our survey. This survey was constructed for the final project of IE 400 course from the University of Illinois at Urbana Champaign. This survey is designed to research the effect of the worldwide pandemic on the psychological wellness and task accomplishing ability of community personnel. The survey will be conducted anonymously, and it will take approximately 5 minutes to complete.

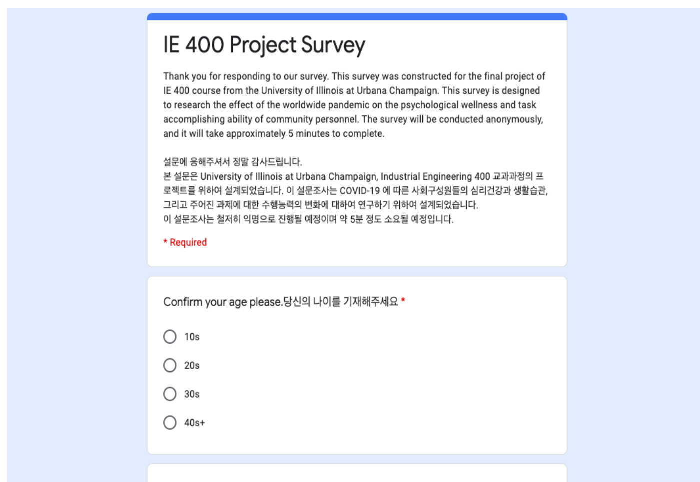
설문에 응해주셔서 정말 감사드립니다.
본 설문은 University of Illinois at Urbana Champaign, Industrial Engineering 400 교과과정의 프로젝트를 위하여 설계되었습니다. 이 설문조사는 COVID-19 에 따른 사회구성원들의 심리건강과 생활습관, 그리고 주어진 과제에 대한 수행능력의 변화에 대하여 연구하기 위하여 설계되었습니다.
이 설문조사는 철저히 익명으로 진행될 예정이며 약 5분 정도 소요될 예정입니다.

* Required

Confirm your age please.당신의 나이를 기재해주세요 *

- 10s
- 20s
- 30s
- 40s+

What is your average amount of sleep per day in hours? 당신의 하루 평균 수면시간은 몇시간입니까? *



IE 400 Project Survey

Thank you for responding to our survey. This survey was constructed for the final project of IE 400 course from the University of Illinois at Urbana Champaign. This survey is designed to research the effect of the worldwide pandemic on the psychological wellness and task accomplishing ability of community personnel. The survey will be conducted anonymously, and it will take approximately 5 minutes to complete.

설문에 응해주셔서 정말 감사드립니다.
본 설문은 University of Illinois at Urbana Champaign, Industrial Engineering 400 교과과정의 프로젝트를 위하여 설계되었습니다. 이 설문조사는 COVID-19 에 따른 사회구성원들의 심리건강과 생활습관, 그리고 주어진 과제에 대한 수행능력의 변화에 대하여 연구하기 위하여 설계되었습니다.
이 설문조사는 철저히 익명으로 진행될 예정이며 약 5분 정도 소요될 예정입니다.

* Required

Confirm your age please.당신의 나이를 기재해주세요 *

- 10s
- 20s
- 30s
- 40s+

Figure 1

Figure 2

All 3 questions were answered on a scale of 1 to 10, 10 being highly anxious and tired. We summed up the values and defined the “tiredness/anxiety index” and set it as a response variable.

Since we now have three non-binary factors, we have decided that the Latin square design is the most sensible model choice. We have conducted an experiment with 4 different colors. Therefore, we divided each block in 4 levels and made sure that each row and column contains all 4 treatments. See table 2 for the design table.

Age	Time that the survey was taken			
	1	2	3	4
1	A	B	C	D
2	B	C	D	A
3	C	D	A	B
4	D	A	B	C

Table 1

Treatment Factor 1: Theme Color of Survey (A=Red, B=Yellow, C=Blue, D=Green)
Blocking Factor 1: Age (1=10s, 2=20s, 3=30s, 4=40s)
Blocking Factor 2: Time of the day (1 = Morning (8am-12pm), 2 = Afternoon (12pm-4pm), 3 = Evening (4pm-8pm) ,4 = Night (8pm-12am)

We need 4*4=16 samples for one replication. In order to create three replications, the survey was given to 48 people. We picked a survey date and went out with an electronic device to the same place 4 times a day for each column block. We were selective with age when asking random passersby to take our survey since we need 12 samples for each age level.

After data collection, we concluded that binding multiple psychological qualities in one linear index would worsen the accuracy of our result. Therefore, we decided to use only the first two questions for our tiredness/anxiety index calculation (We got rid of question 3 mentioned above). The maximum value of the response variable is 20, whereas the minimum value is 2. See thale 2 for the data that we have collected for all replication.

Age	Time that the survey was taken			
	1	2	3	4
1	A (16,18, 20)	B (11, 12, 13)	C (4, 8, 8)	D (8, 11, 8)
2	B (13, 15, 13)	C (8, 2, 7)	D (8,11, 10	A (18, 17, 18
3	C (7, 17, 5)	D (5, 5, 7)	A (15, 20, 13)	B (10, 9, 10)
4	D (2, 4, 3)	A (8, 12, 19)	B (9, 5, 7)	C (2, 5, 2)

Table 2

Statistical Analysis procedure

Latin Square Model with replication

$$Y_{ijkm} = \mu + \rho_i + \kappa_j + \tau_k + \epsilon_{ijkm}$$

μ is a constant
ρ_i row blocking effect (age group) subject to $\Sigma\rho_i = 0$
κ_j column blocking effect (time the survey was taken) subject to $\Sigma\kappa_j = 0$
τ_k Latin Letter treatment effect (Color of the survey) subject to $\Sigma\tau_k = 0$
ϵ_{ijkm} are independent $N(0, \sigma^2)$
$i, k, j = 1, ..., 4$, $m = 1...3$

First we have composed an Latin Square model with replication. We set age group as a row blocking effect and time the survey was taken as a column block. Treatment factor is color of the survey with color red, green, blue, and yellow.

ANOVA Table

The GLM Procedure

Dependent Variable: resp

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	9	960.687500	106.743056	17.81	<.0001
Error	38	227.791667	5.994518		
Corrected Total	47	1188.479167			

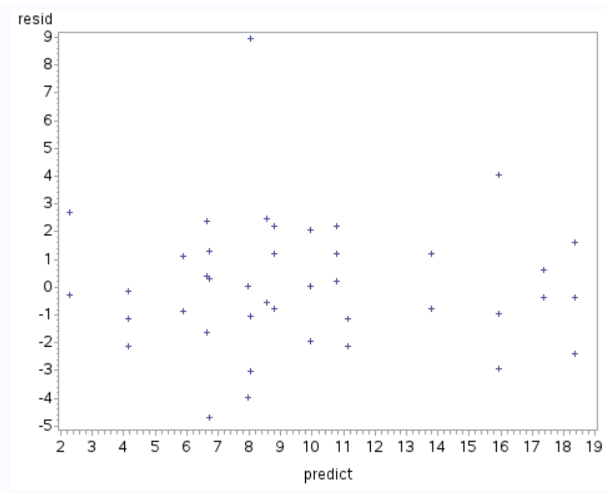
R-Square	Coeff Var	Root MSE	resp Mean
0.808333	25.05795	2.448370	9.770833

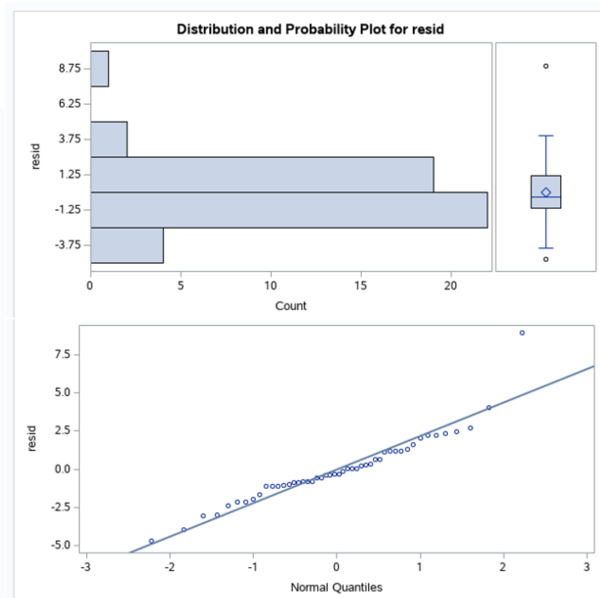
Source	DF	Type I SS	Mean Square	F Value	Pr > F
age	3	272.3958333	90.7986111	15.15	<.0001
time	3	45.5625000	15.1875000	2.53	0.0713
trt	3	642.7291667	214.2430556	35.74	<.0001

Source	DF	Type III SS	Mean Square	F Value	Pr > F
age	3	272.3958333	90.7986111	15.15	<.0001
time	3	45.5625000	15.1875000	2.53	0.0713
trt	3	642.7291667	214.2430556	35.74	<.0001

Above table shows the result of ANOVA procedure. Interesting part of the model is that Latin square model with replication is different from that of the original Latin square model. One with replication shows an interesting pattern in the degrees of freedom for error term. Original Latin square model has a degrees of freedom of (r-1)(r-2), which is supposed to be 6, if there were not any replication. But for the one with replication it follows the term of $n*r^2-3*r+2$, which is shown correctly in the table.

Checking model assumption





Figures above show the fitted vs residual graph (Left) and Distribution / QQplot (Right). As it is shown in the fitted vs residual, the dots in the graph are evenly distributed in a way that it fits in two lines that are horizontal and parallel to the x axis. The data points are clustered around the region of 0 residual shows that the data is showing good overall shape. This shows that the data we have obtained shows constant variance.

For QQplot and distribution plot, data points show a certain pattern. The pattern almost matches the line provided in the qqplot. Distribution plot shows that there are certain points that deviate but the majority of the data shows a good trend of normality. The univariate procedure does not seem to assume normality, however, we have to consider the idea behind the central limit theorem. Central limit theorem shows that the distribution of sample mean reaches normality when the sample quantity is sufficient. We have obtained a sample size of 48 which is greater than 30, which is known to be the standard point of deciding whether the sample is large or not. So, it is supposed to reach normality considering the central limit theorem, and the QQplot proves that it does. Therefore we can proceed with our statistical analysis.

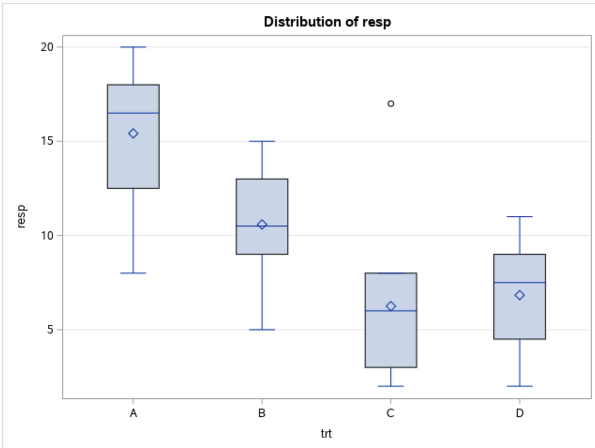
Tukey's Studentized Range (HSD) Test for resp

Note: This test controls the Type I experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	38
Error Mean Square	5.994518
Critical Value of Studentized Range	3.79925
Minimum Significant Difference	2.6852

Comparisons significant at the 0.05 level are indicated by ***.

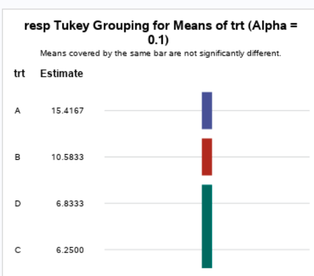
trt Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
A - B	4.8333	2.1481	7.5186	***
A - D	8.5833	5.8981	11.2686	***
A - C	9.1667	6.4814	11.8519	***
B - A	-4.8333	-7.5186	-2.1481	***
B - D	3.7500	1.0648	6.4352	***
B - C	4.3333	1.6481	7.0186	***
D - A	-8.5833	-11.2686	-5.8981	***
D - B	-3.7500	-6.4352	-1.0648	***
D - C	0.5833	-2.1019	3.2686	
C - A	-9.1667	-11.8519	-6.4814	***
C - B	-4.3333	-7.0186	-1.6481	***
C - D	-0.5833	-3.2686	2.1019	



Tukey's Studentized Range (HSD) Test for resp

Note: This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.1
Error Degrees of Freedom	38
Error Mean Square	5.994518
Critical Value of Studentized Range	3.35428
Minimum Significant Difference	2.3708



Above shows the boxplot with treatment, color of the survey, on the x axis and response tiredness and anxiety level of the y axis. The boxplot shows the difference of mean response among the different colors. As mentioned above, A = red, B = Yellow, C = Blue, D = Green. According to the box plot, tiredness level of A,B,C shows significant difference just by the look. The box plot in appearance shows that the tiredness / anxiety level was greatest when the survey color was red. Then the yellow survey showed 2nd highest tiredness / anxiety level, and blue and green survey seemed to show similar tiredness / anxiety level, with being the two lowest. Although there needs to be further statistical analysis to confirm that they actually differ, just by looking at the mean of the box plot we could see the difference. However, when looking at the box plot of C and D, it is hard to tell if there are any differences in the mean, between those two. Therefore, we performed Tukey analysis with setting $\alpha = 0.05$.

When the $\alpha = 0.05$, tukey comparison indicates that all of the pairs except pair C and D do not contain 0 in the interval. This means that all of the pairs except C and D show significant difference in the mean of level of tiredness / anxiety. However, pair C and D contains 0 in its interval meaning that given a 95% interval there is no significant difference between response variables when treatment C (color blue) and D (color green) is applied in the survey. To briefly summarize, among all the pairs, the survey response of blue survey and green survey show that there is no significant difference between those two.

To proceed with the hypothesis testing of the treatment, we have used $\alpha = 0.05$.

Hypothesis Testing for Latin Letter Treatment (Color of the survey)
Ho : $\tau_k = 0$
Hα : not all τ_k are zero

Test Statistic: F * = (MSTR /MSRem) = (214.2430556/5.994518) = 35.74983
Decision Rule:
if F * < F(r-1,n*r^2-3*r+2) (1-α) = 2.852, conclude Ho
if F * > F(r-1,n*r^2-3*r+2) (1-α) = 2.852, conclude Hα

Conclusion: The p-value of this treatment factor from ANOVA table is less than 0.0001, which is less than α=0.05 Also, our test statistic is larger than the critical value 2.852. Therefore, we reject the null hypothesis and conclude that the color of the survey has statistical significance to the tiredness/anxiety index.

Although hypothesis testing for blocking effect is not usually used for the model because blocks are meant to reduce the experimental error variability, we decided to analyze the blocking effects.

Hypothesis Testing for Blocking effect (Age group of the experimental units)
Ho : $\rho_i = 0$
Hα : not all ρ_i are zero

Test Statistic: F * = (MSRow /MSRem) = (90.7986/5.994518) = 15.1469
Decision Rule:
if F * < F(r-1,n*r^2-3*r+2) (1-α) = 2.852, conclude Ho
if F * > F(r-1,n*r^2-3*r+2) (1-α) = 2.852, conclude Hα
Conclusion: The p-value of this treatment factor from ANOVA table is less than 0.0001, which is less than α=0.05 Also, our test statistic is larger than the critical value 2.852. Therefore, we reject the null hypothesis and conclude that the age group has statistical significance to the tiredness/anxiety index.

Hypothesis Testing for Blocking effect (Time the survey was taken by the experimental units)
Ho : $\kappa_j = 0$
Hα : not all κ_j are zero

Test Statistic: F * = (MSCol /MSRem) = (15.1875/5.994518) = 2.53
Decision Rule:
if F * < F(r-1,n*r^2-3*r+2) (1-α) = 2.852, conclude Ho
if F * > F(r-1,n*r^2-3*r+2) (1-α) = 2.852, conclude Hα

Conclusion: The p-value of this treatment factor from ANOVA table is less than 0.0713, which is greater than α=0.05. Also, our test statistic is smaller than the critical value 2.852. Therefore, we fail to reject the null hypothesis and conclude that the time the survey was taken has no statistical significance to the tiredness/anxiety index.

To summarize the three hypothesis testing of two blocking effects and one treatment effect, we can conclude that our treatment factor, color of the survey, showed that depending on the color there are it is statistically significant that the experimental units(people who took the survey) would show difference in the tiredness / anxiety level. For the two blocking effects, age group turned out to have a significant difference among the 4 levels, to the response of the survey, whereas time of the survey taken did not show any significance difference depending on the level.

Sources of error / Comments

Since we have used Latin square design to explore multiple factors with limited samples, we have not considered the interaction effect of factors in our study. Also, Latin square only allows the use of the same factor levels for treatment and blockings. Therefore, if we were forced to use a limited number of treatments since we would have to increase the blocking factor levels along with the number of treatments.

We attempted to randomize our sample as much as possible. However, the sample pools could still be biased since we conducted the survey at the same place.

As we mentioned above, we have told our samples that this study was designed to research the relationship between COVID-19 and their task accomplishing ability. Therefore, their personal experience with regards to the COVID-19 might have affected their psychological status while taking the survey. For example, if they have a close acquaintance who have recently tested positive, such experience would have most likely raised their anxiety.

In fact, their psychological status could have been affected by various other factors such as physical environmental condition of the day. In the future, we could use more cost to conduct more “controlled” experiments to minimize the error of the research. Also, we could maximize ones’ exposure to colors other than the theme color of the survey.

Non-technical conclusion

Our initial objective was to conduct a statistical experiment to find if there is a relationship between visual effect with different colors and the level of tiredness and anxiety of humans. We created online surveys with different background colors and investigated samples’ level of anxiety and tiredness levels. Through statistical analysis, we have concluded that color effects using red raises the tiredness and anxiety level of people, whereas blue and green keep them tranquile and relaxed. Also, the level of anxiety and tiredness seemed to differ significantly by their age group as well. The result of our experiment suggests that the level of anxiety and tiredness can be partially controlled by the visual exposure to different colors. This conclusion can be further studied and used applied in the field of psychiatry or brand marketing.

Code Appendix

```
data pilot;
input age time trt $ resp;
datalines;
1 1 A 16
1 2 B 11
1 3 C 4
1 4 D 8
2 1 B 13
2 2 C 8
2 3 D 8
2 4 A 18
3 1 C 7
3 2 D 5
3 3 A 15
3 4 B 10
4 1 D 2
4 2 A 8
4 3 B 9
4 4 C 2
1 1 A 18
1 2 B 12
1 3 C 8
1 4 D 11
2 1 B 15
2 2 C 2
2 3 D 11
2 4 A 17
3 1 C 17
3 2 D 5
3 3 A 20
3 4 B 9
4 1 D 4
4 2 A 12
4 3 B 5
```

```
4 4 C 5
1 1 A 20
1 2 B 13
1 3 C 8
1 4 D 8
2 1 B 13
2 2 C 7
2 3 D 10
2 4 A 18
3 1 C 5
3 2 D 7
3 3 A 13
3 4 B 10
4 1 D 3
4 2 A 10
4 3 B 7
4 4 C 2
;
proc glm data=pilot;
class age time trt;
model resp=age time trt;
means trt/ lines tukey alpha= 0.1 cldiff ;
output out=temp r=resid p=predict;
run;

data residuals;
set temp;
run;

goptions hsize=5;
goptions vsize=4;
proc gplot data=residuals;
plot resid*predict;
run;

goptions hsize=5;
goptions vsize=4;
proc univariate normal plot data=residuals;
   var resid;
   title 'Distribution of the residuals.';
run;
```