C2M3_Peer_Reviewed

March 1, 2024

1 C2M3: Peer Reviewed Assignment

1.0.1 Outline:

The objectives for this assignment:

1. Motivate the use of two-way ANOVA through real data analysis examples.
2. Interpret the two-way ANOVA model, with and without interaction terms.
3. Construct and interpret interaction plots to visually assess the importance of an interaction term.
4. Conduct hypothesis tests to decide whether a two-way ANOVA interaction term is statistically significant.
5. Use the two-way ANOVA and ANCOVA models to answer research questions using real data.

General tips:

1. Read the questions carefully to understand what is being asked.
2. This work will be reviewed by another human, so make sure that you are clear and concise in what your explanations and answers.

[16]:
```
# Load Required Packages
library(tidyverse)
library(ggplot2) # a package for nice plots!
library(dplyr)
library(emmeans)
```

2 Problem 1: e-reader data

In this assignment, we learn to answer our two-way ANOVA research questions through the analysis of real data. We will use the ereader data. The study that generated these data can be found here: P.-C. Chang, S.-Y. Chou, K.-K. Shieh (2013). "Reading Performance and Visual Fatigue When Using Electronic Displays in Long-Duration Reading Tasks Under Various Lighting Conditions," Displays, Vol. 34, pp. 208-214.)

Electronic paper display devices, such as the Amazon Kindle have changed the way that people read. But has it changed for the better? In a 2013 study titled "Reading Performance and Visual

Fatigue When Using Electronic Displays in Long-Duration Reading Tasks Under Various Lighting Conditions", researchers set out to ask whether reading speed (a continuous variable) differed across different electronic paper displays. In addition, they were also interested in whether different lighting conditions impacted reading speed. As such, this experiment had one response with two different factors:

1. Device type: three different types.
    1. Sony PRS-700 with a 6-in. display, 800×600 resolution;
    2. Amazon Kindle DX with a 9.7-in. display, 1200×824 resolution; and
    3. iRex 1000S with a 10.2-in. display, 1024×1280 resolution.
2. Lighting Condition: four different conditions (200Lx,500Lx, 1000Lx, 1500Lx), Lx = lux, one lumen per square meter
3. Reading Time: measured in seconds.

With these data, we might ask the following **research questions**:

1. Are the effects of device type significant? That is, is there evidence that suggests that individuals read at different speeds based on the device that they are using?
2. Are the effects of lighting conditions significant? That is, is there evidence that suggests that individuals read at different speeds based on the reading lighting conditions?
3. Do device type and lighting conditions *interact*? For example, Suppose that, on average, people can read for longer on device A than on device B, in low light. Is that trend the same in medium light, or bright light? If not, for example, if B is better than A in bright light, then type and lighting interact.

Through this entire analysis, let's set $\alpha = 0.05$.

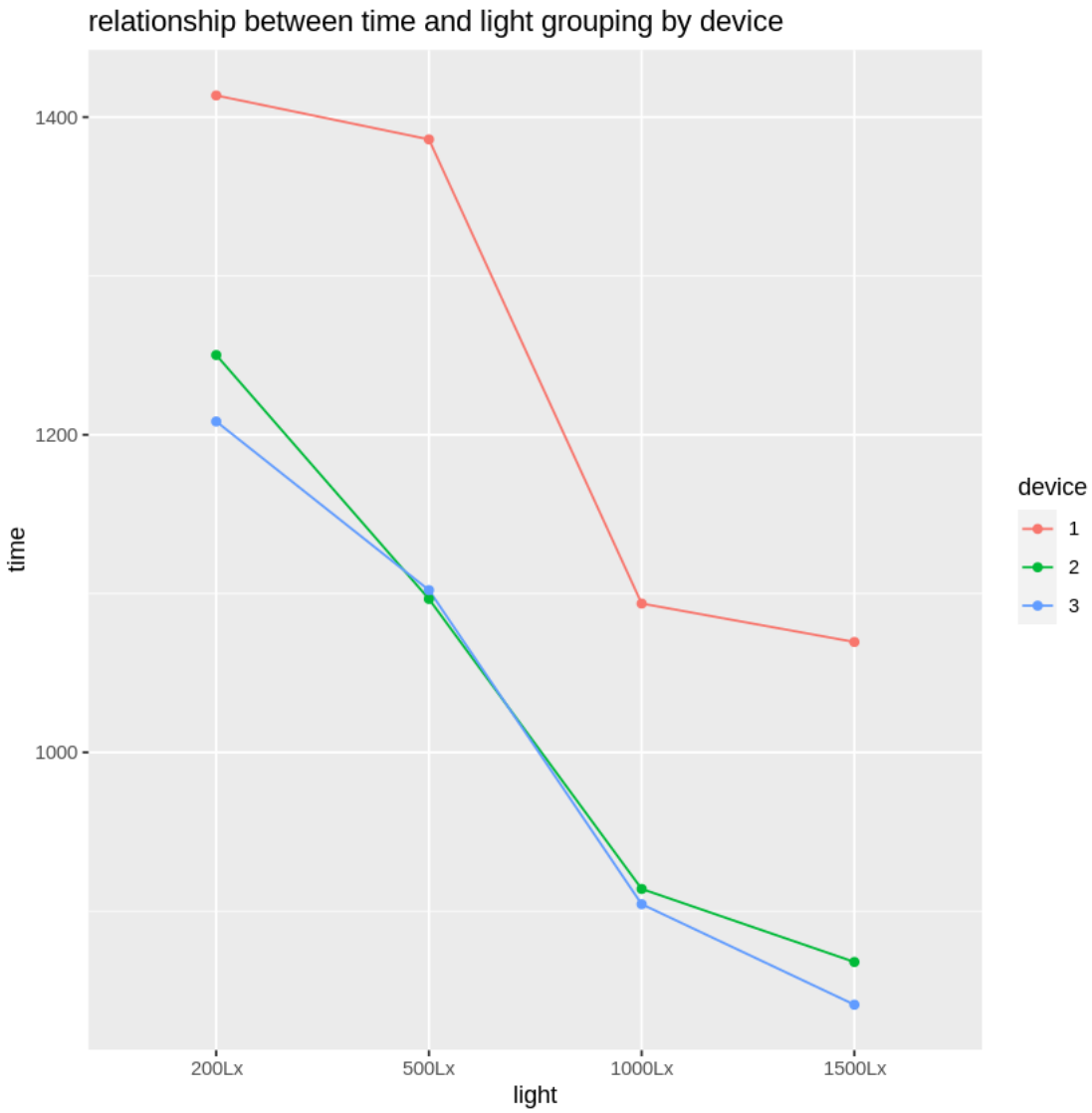
First, let's read in the data, and store the appropriate variables as factors.

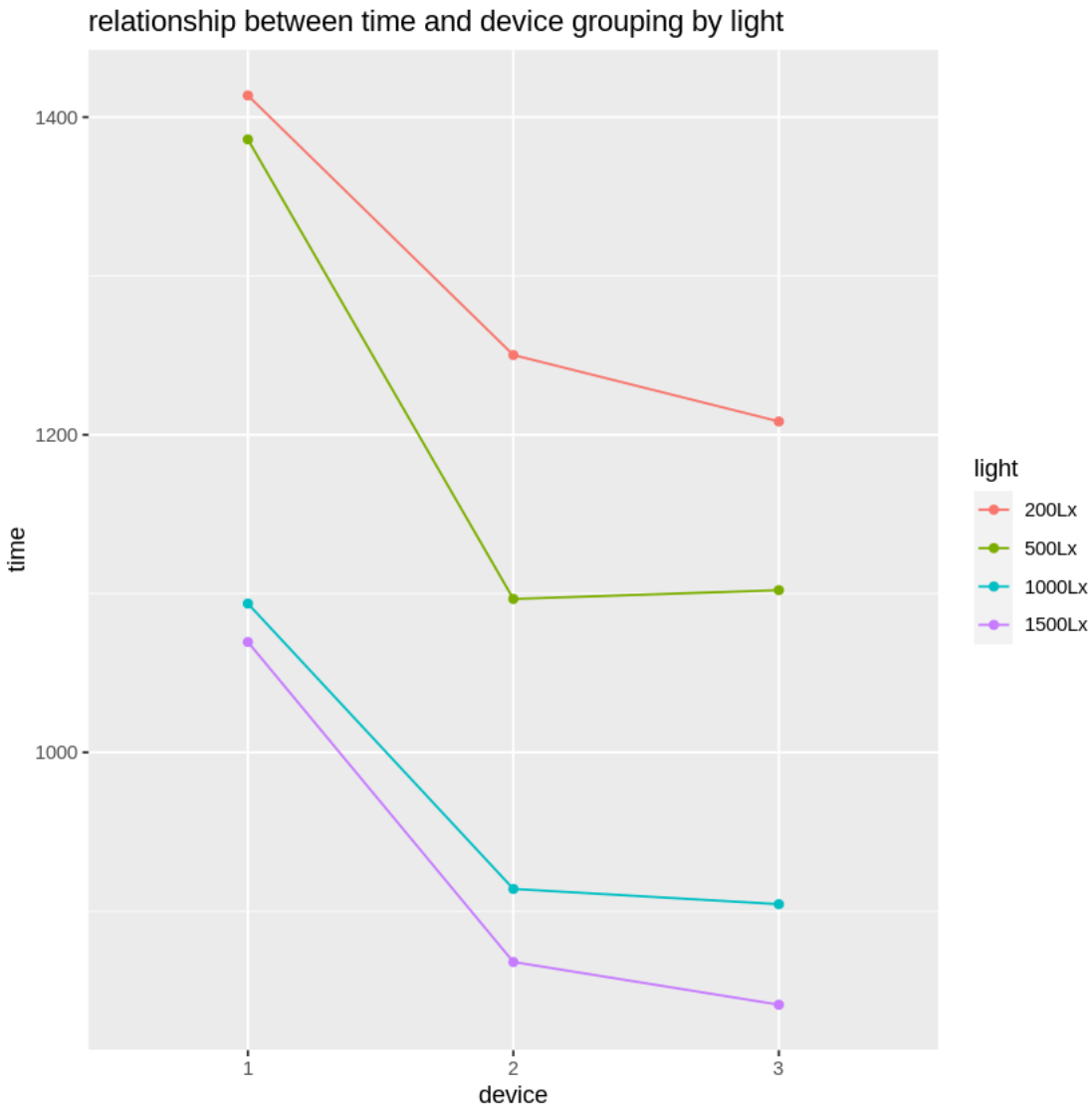
[17]:
```
# Load the data
read = read.csv("ereader.txt", sep="\t")

names(read) = c("device", "light", "time")
read$device = as_factor(read$device)
read$light = as.factor(read$light)
read$light = recode(read$light, "1" = "200Lx", "2" = "500Lx", "3" = "1000Lx",␣
↪"4" = "1500Lx")

summary(read)
```

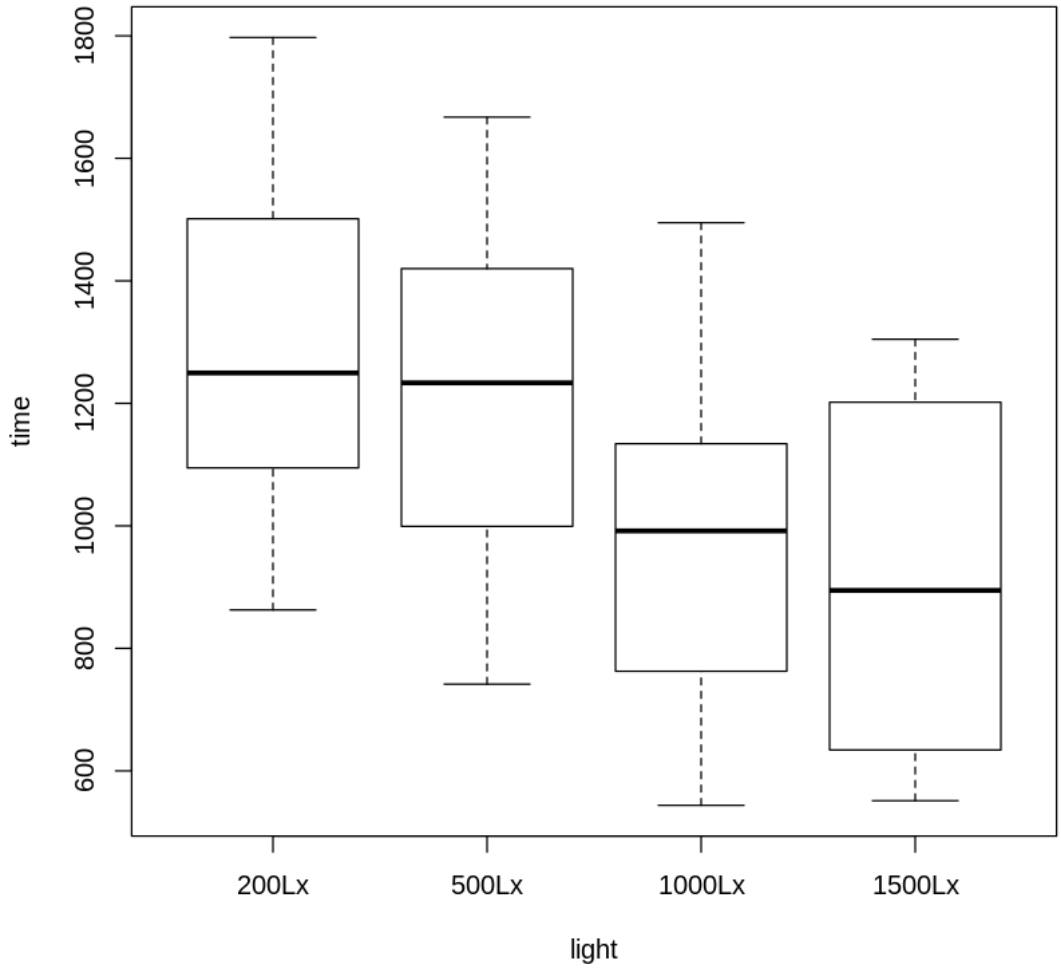
```
 device    light         time
 1:19   200Lx :14   Min.   : 543.8
 2:20   500Lx :15   1st Qu.: 861.4
 3:20   1000Lx:15   Median :1105.4
        1500Lx:15   Mean   :1090.2
                    3rd Qu.:1300.0
                    Max.   :1797.2
```

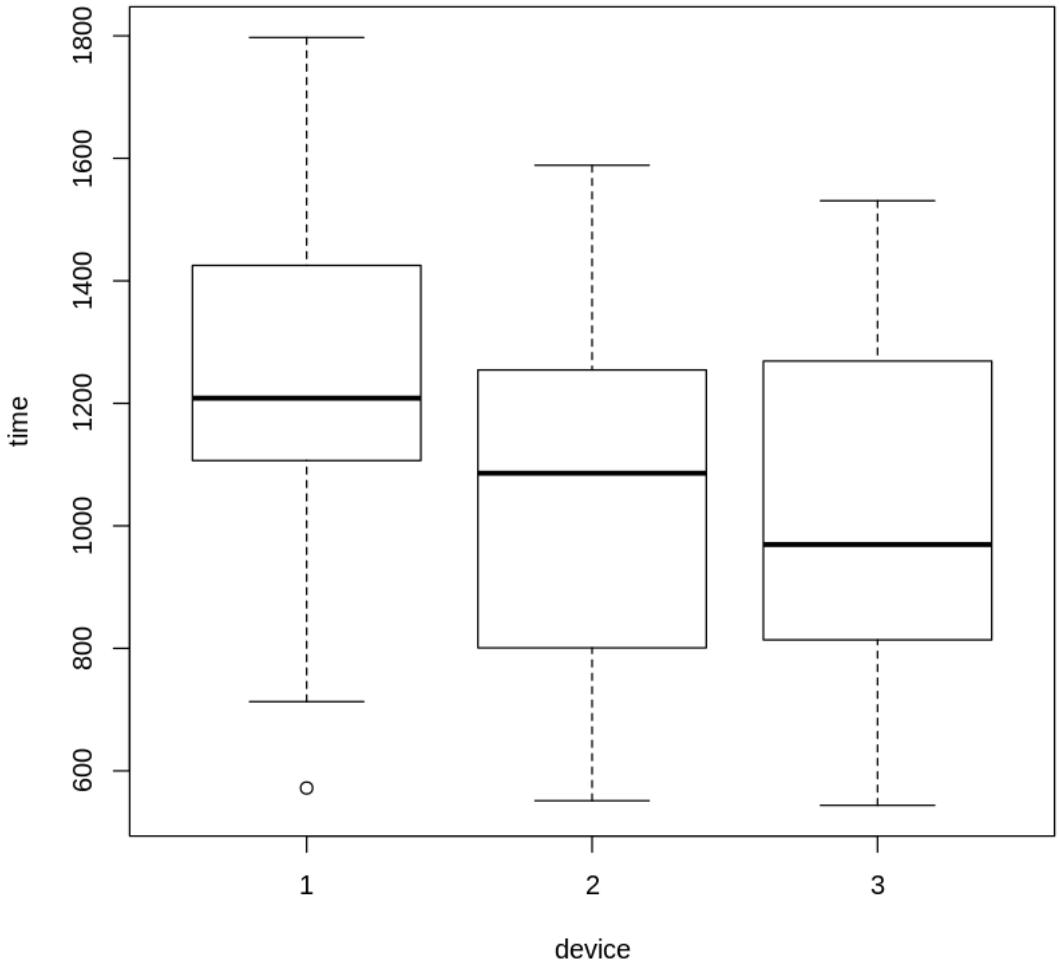
1.(a) Construct interaction plots, and visually assess and comment on whether interactions are present.

[18]:
```
# Your Code Here
read.aggregate = aggregate(time~light+device,read,FUN=mean)

ggplot(read.aggregate, aes(x=light, y=time, group=device, color=device)) +
    ggtitle('relationship between time and light grouping by device') +
    geom_line() +
    geom_point()

ggplot(read.aggregate, aes(x=device, y=time, group=light, color=light)) +
    ggtitle('relationship between time and device grouping by light') +
    geom_line() +
    geom_point()

plot(time~light+device,read)
```


relationship between time and light grouping by device
1400
1200
1000
time
200Lx
500Lx
1000Lx
1500Lx
light
device
1
2
3


relationship between time and device grouping by light
1400
1200
1000
time
1
2
3
device
light
200Lx
500Lx
1000Lx
1500Lx


time
600
800
1000
1200
1400
1600
1800
200Lx
500Lx
1000Lx
1500Lx
light



ANSWER 1.(a) From the interaction plots, it seems that may be an interaction between the factors device and light. The graphs seems to have similar shapes with changing slopes, and even an intersection between device 2 and 3 at 500Lx in the first plot, which would imply that there is an interaction present between factors. The second plot shows no interaction. We do not know whether this interaction is significant, though. Of course, we will now test this more rigorously using statistics, as visuals are to be used only for getting an idea of trends.

1.(b) Now, let's formally test for an interaction. Fit a model with an interaction, and one without, and conduct an F-test. State the appropriate decision for the test.

[21]:
```
# Your Code Here
read.lm.interaction = lm(time~light+device+light:device,read)
read.lm.no.interaction = lm(time~light+device,read)
```

```
anova(read.lm.no.interaction,read.lm.interaction)
```

A anova: 2 × 6

	Res.Df <dbl>	RSS <dbl>	Df <dbl>	Sum of Sq <dbl>	F <dbl>	Pr(>F) <dbl>
1	53	3628970	NA	NA	NA	NA
2	47	3603108	6	25861.55	0.05622427	0.9992146

ANSWER 1.(b) From the ANOVA table, we can see that the p-value for the F-Test that compares the two models, one with and the other without an interaction term, is much greater than our alpha value: 0.999»0.05. Thus, the F-Test suggests that the model without the interaction term is sufficient to model the data, implying that any interaction is not significant.

1.(c) Before we interpret this model with respect to research question #1 above (just below the data description), let's decide whether the differences that the model reports are statistically significant.

Investigate this question using Bonferroni post hoc comparisons. That is, conduct all pairwise post hoc comparisons for device type using a Bonferroni correction and an overall type I error rate of $\alpha = 0.05$. Comment on the results.

[22]:
```
# Your Code Here
# needed to restart kernel to access lsmeans/pairs for some reason
av = aov(read.lm.no.interaction)
pairs(lsmeans(read.lm.no.interaction, "device"), adjust = "bonferroni")
```

```
 contrast estimate   SE df t.ratio p.value
 1 - 2       209.7 83.9 53 2.500   0.0466
 1 - 3       227.9 83.9 53 2.717   0.0266
 2 - 3        18.2 82.7 53 0.220   1.0000

Results are averaged over the levels of: light
P value adjustment: bonferroni method for 3 tests
```

ANSWER 1.(c) The Bonferroni corrected pairwise post-hoc comparisons for device type showed that there is not a statistically significant difference between the mean in reading time between device 2 and 3, but the difference in mean reading time between device 1 and 3 is significant. Likewise, the difference between device 1 and 2 is significant.

1.(d) Using the post hoc comparisons from above, let's focus on research question #1 from above: Are the effects of device type significant? That is, is there any evidence that suggests that individuals read faster or slower based on the device that they are using

ANSWER 1.(d) The post-hoc comparison above suggests that device type is significant to reading time when comparing the Sony PRS-700 to the iRex 100s and the Sony PRS-700 to the Amazon Kindle DX. The analysis suggests that individuals read neither faster nor slower between using an Amazon Kindle DX or an iRex 1000s.

[ ]:
```
# Your Code Here
```