Not Always A Matter Of Context: direct effects of red on arousal but context-dependent moderations on valence

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Paper. Buechner and Maier (2016) Not always a matter of context: direct effects of red on arousal but context-dependent moderations on valence. *PeerJ*

Summary. This study aimed to determine whether colors intrinsically elicit different degrees of arousal, and whether their perceptual effects on valence are dictated by the contextual circumstances in which the colors are experienced. To investigate this question, Buechner and Maier (2016) sorted subjects into one of ***four experimental categories***. These categories consisted of assessing the arousal and valence properties of either:

- four "test-relevant" pictures framed in red
- four "test-relevant" pictures framed in blue
- four "neutral" pictures framed in red
- four "neutral" pictures framed in blue

To assess arousal, participants in each category were asked: "Describe how physiologically arousing do you think [the situation in this picture] is". To assess valence, participants in each category were asked: "Describe how unpleasant do you think [the situation in this picture] is". In response to each question, participants assigned each picture a number from 1 (not at all) to 9 (extremely). The authors then take the **mean** of the **arousal** and **valence ratings across the four pictures** rated by a given participant.

Hypothesis. The color **red** should increase arousal perceptions for both neutral and test-relevant picture contexts, but it should increase valence perceptions only for test-relevant pictures.

The dataframe contains rows of subjects with their corresponding assessement of a given picture as physically arousing or unpleasant (a measure of valence).

```r
library(foreign)
library(dplyr)
library(tidyverse)
library(DescTools)

color_data_pr = read.csv("color_data_pr.csv")
```

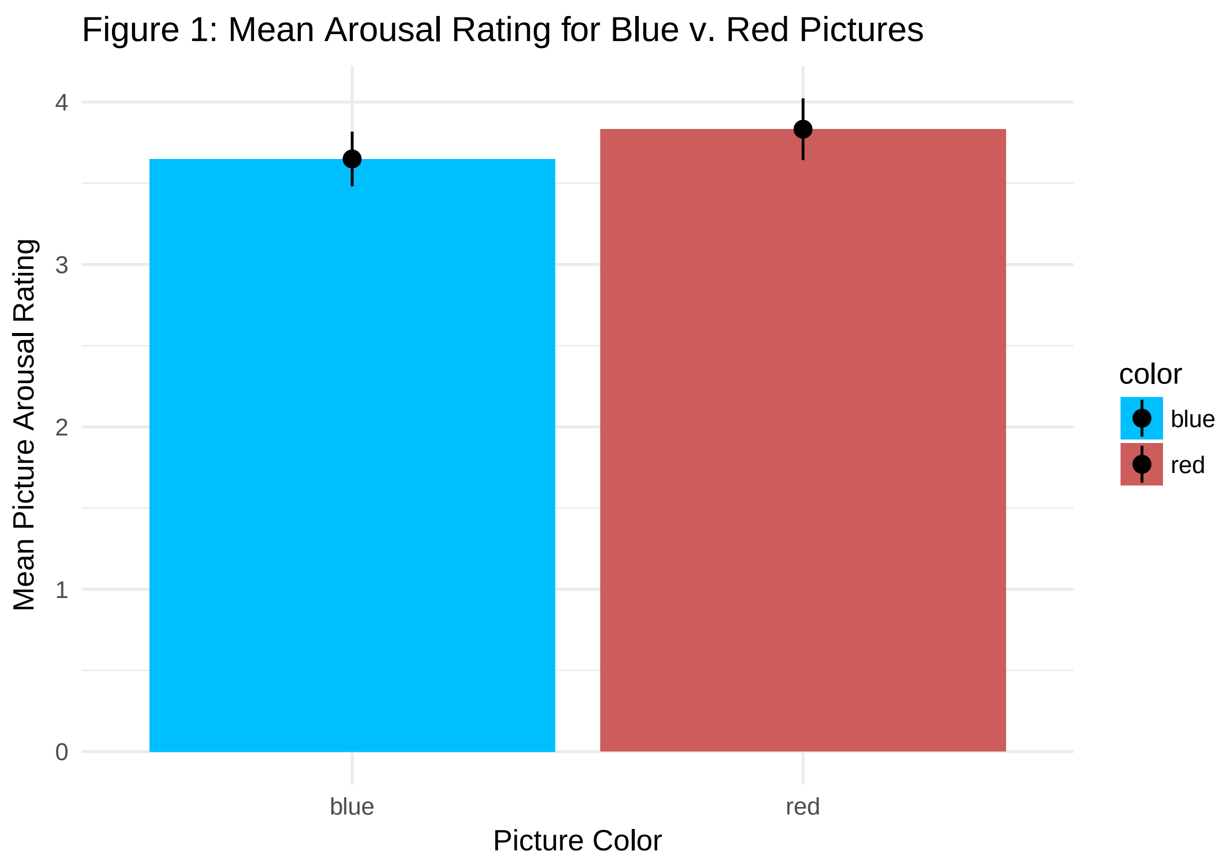
Replicating and Improving on Analyses and Figures

A note on the response variables used in this experiment: the four pictures presented to each participant contained figures that were matched for unpleasantness (valence) and arousal quality by "experts". However, it is not clear that this expert assessment guarantees uniform responses across the four different pictures (for instance, picture1 may have elicited an arousal rating of 2, whereas picture2 elicited an arousal rating of 7 – taking the mean of these would not necessarily constitute a meaningful arousal assesment). So it might be wise to take the following results with this caveat in mind, even though we trust that authors invested time in norming their stimuli.

Arousal

_Does color modulate arousal? And, what is the influence of context?

```
# Figure 1 replicated
fig1 <- ggplot(color_data_pr, aes(x=color, Pic_arousal_MEAN, fill = color)) +
  geom_bar(stat="summary", fun.y="mean", position="dodge") +
  stat_summary(fun.y = function(x){mean(x)},
               fun.ymin = function(x){mean(x) - 2*sd(x)/sqrt(length(x))},
               fun.ymax = function(x){mean(x) + 2*sd(x)/sqrt(length(x))},
               geom= 'pointrange') +
  scale_fill_manual(values = alpha(c("deepskyblue", "indianred"), 1))+
  labs(title = 'Figure 1: Mean Arousal Rating for Blue v. Red Pictures',
       y = 'Mean Picture Arousal Rating',
       x = 'Picture Color') +
  theme_minimal()
fig1
```




```
# ANOVA with color and context as between-subjects factors for arousal ratings.
# no significant interaction between color and context on arousal ratings.

# to get the reported effect of color
interact.aro.color = aov(data= color_data_pr, Pic_arousal_MEAN ~ pic * color)
summary(interact.aro.color)
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## pic           1 100.97  100.97 113.604 <2e-16 ***
## color         1   3.85    3.85   4.335 0.0382 *
```

```
## pic:color     1   0.98    0.98   1.101 0.2948
## Residuals   301 267.53    0.89
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

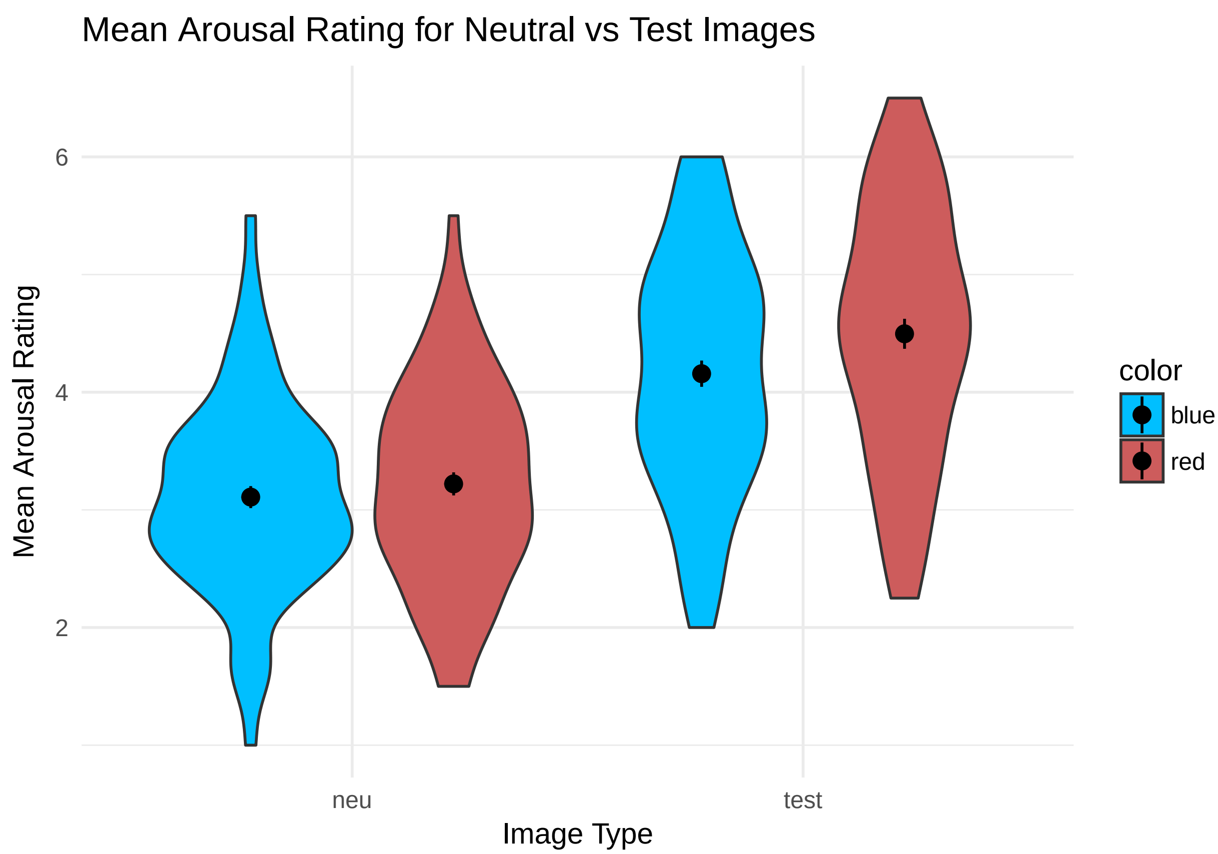
```
# to get the reported effect of context (note: the variable "pic" indicates context, whether test-relev
(interact.aro.pic = summary(aov(data= color_data_pr, Pic_arousal_MEAN ~ color * pic)))
```

```
##              Df Sum Sq Mean Sq F value Pr(>F)
## color         1   2.55    2.55   2.873 0.0911 .
## pic           1 102.27  102.27 115.066 <2e-16 ***
## color:pic     1   0.98    0.98   1.101 0.2948
## Residuals   301 267.53    0.89
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

A **very** subtle effect of **color** on mean arousal ratings **(F(1,301) = 4.34, p = 0.038)**. In the original paper, authors rescale their y-axis to visually enhance the difference in means. Additionally, we only obtain matching values for the reported F-statistics if we run two different ANOVAs, with different ordering of the predictors. However, the paper reports the results as though they were generated from the same analysis. Interestingly, the main effect of color happens to wash out when it is used to explain most of the variance in the model **(F(1,301) = 2.87, p = 0.0911)**.

We then created violin plots in order to get a better sense of how the differences in mean arousal were distributed within each color and context condion.
We separate the arousal ratings based on image type and colour frame. On average, the content-matched negative images (test condition) were rated as more arousing compared to neutral valence images, regardless of colour framing. Furthermore, content-matched negative images were rated as more arousing when framed with red, compared to the same images framed with blue.

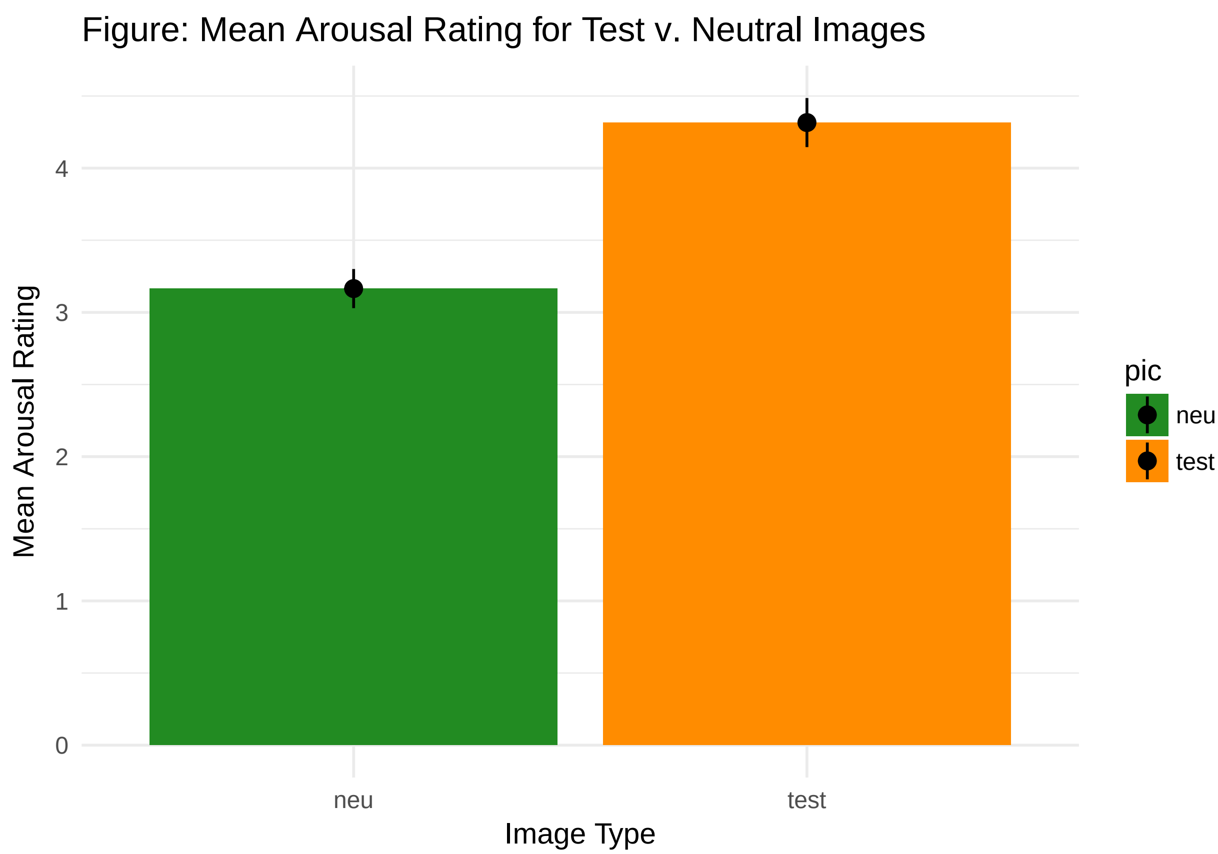
```
### Violin Plot for Arousal Mean
arousal.violin <- ggplot(color_data_pr, aes(x=pic, Pic_arousal_MEAN, fill=color))+
  geom_violin() +
  stat_summary(fun.data = mean_se, geom = 'pointrange', color='black', position = position_dodge(.9)) +
  scale_fill_manual(values = alpha(c("deepskyblue", "indianred"), 1))+
  labs(title = 'Mean Arousal Rating for Neutral vs Test Images',
       y = 'Mean Arousal Rating',
       x = 'Image Type') +
  theme_minimal()
arousal.violin
```



Visually, it looks as thought the larger difference in arousal mean is within the test condition. Next, we decided to further investigate the influence of context on arousal.

We confirmed that the test condition is rated more arousing than the neutral condition.

```
# New plot showing difference between test and neutral contexts

# Similar to Fig 1, but with test vs neu on arousal
fig1.aro.pic <- ggplot(color_data_pr, aes(x=pic, Pic_arousal_MEAN, fill = pic)) +
  geom_bar(stat="summary", fun.y="mean", position="dodge") +
  stat_summary(fun.y = function(x){mean(x)},
               fun.ymin = function(x){mean(x) - 2*sd(x)/sqrt(length(x))},
               fun.ymax = function(x){mean(x) + 2*sd(x)/sqrt(length(x))}, geom= 'pointrange') +
  scale_fill_manual(values = alpha(c("forestgreen", "darkorange"), 1)) +
  labs(title = 'Figure: Mean Arousal Rating for Test v. Neutral Images',
       y = 'Mean Arousal Rating',
       x = 'Image Type')+
  theme_minimal()
fig1.aro.pic
```



There was a strong effect of **context** on mean arousal ratings **(F(1,301) = 115.01, p < .001)**. This result is mostly omitted in the article's discussion of results. They suggest that red is inherently more arousing than blue, without discussing the influence of context (for the arousal ratings specificaly).

We then ran an ANCOVA to look at the the main effect of color on arousal when context was acounted for.

```
# ancova for arousal as a factor of color, acounting for influcence of context.

anova(lm(data=color_data_pr, Pic_arousal_MEAN ~ pic + color))
```

```
## Analysis of Variance Table
##
## Response: Pic_arousal_MEAN
##            Df  Sum Sq Mean Sq  F value  Pr(>F)
## pic         1 100.972 100.972 113.5663 < 2e-16 ***
## color       1   3.853   3.853   4.3335 0.03821 *
## Residuals 302 268.510   0.889
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

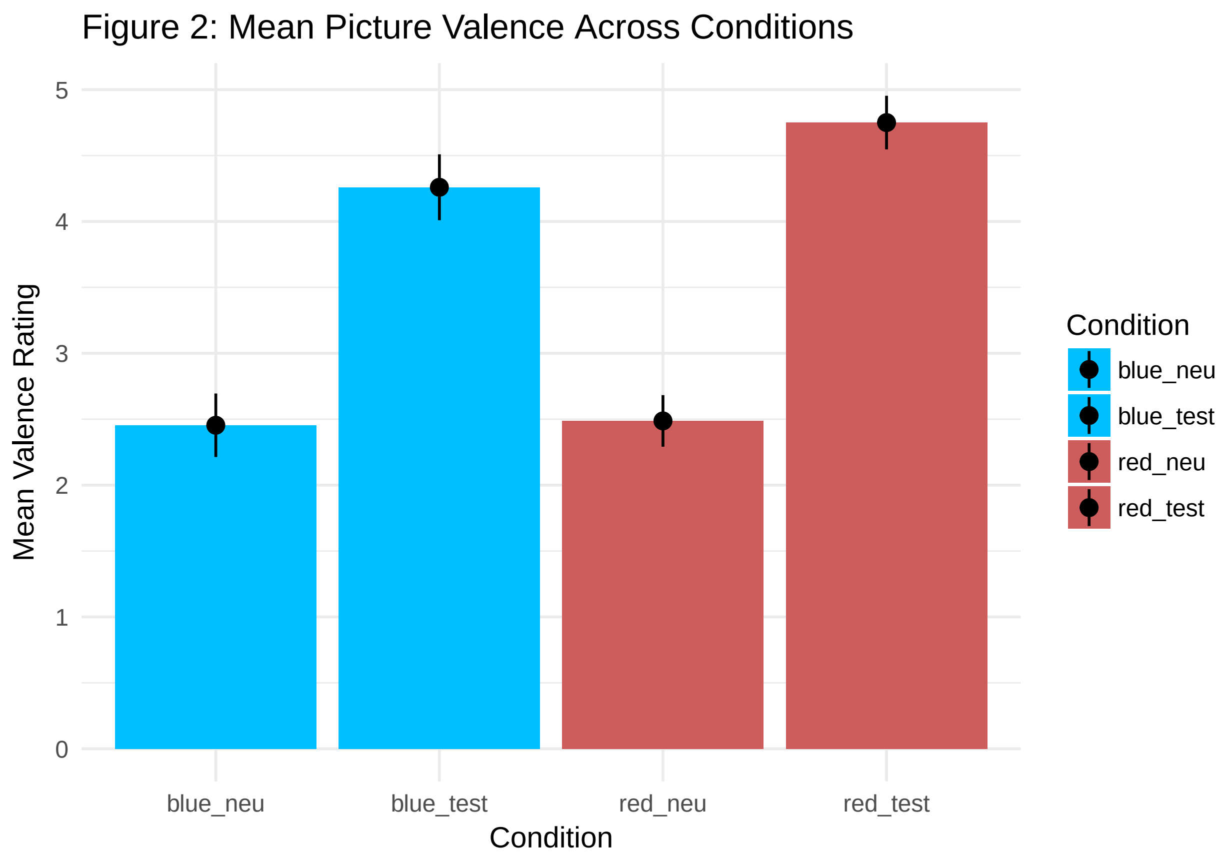
This gave a smaler f-value, but the p-value remained the same (F(1,302) = 3.853, p = 0.038).

We can conlude that there is an effect of color on arousal, however it is not as strong as the effect of context on arousal.

Valence

Effects of color and context on valence ratings

```
# Figure 2 replicated

fig2.color <- ggplot(color_data_pr, aes(x=Condition, Pic_valence_MEAN, fill = Condition)) +
  geom_bar(stat='summary', fun.y='mean') +
  stat_summary(fun.y = function(x){mean(x)},
               fun.ymin = function(x){mean(x) - 2*sd(x)/sqrt(length(x))},
               fun.ymax = function(x){mean(x) + 2*sd(x)/sqrt(length(x))},
               geom= 'pointrange') +
  scale_fill_manual(values = alpha(c("deepskyblue", "deepskyblue", "indianred", "indianred"), 1)) +
  labs(title = 'Figure 2: Mean Picture Valence Across Conditions',
       y = "Mean Valence Rating",
       x = "Condition") +
  theme_minimal()
fig2.color
```



We chose illistrate the data with violin plots here instead of bar plots to better represent the distribution.

```
### Violin Plot for Valence Mean -- need to fix y-scale

valence.violin <- ggplot(color_data_pr, aes(x=pic, Pic_valence_MEAN, fill=color)) +
  geom_violin() +
  stat_summary(fun.data = mean_se,
               geom = 'pointrange',
               color='black',
               position = position_dodge(.9))+
  scale_fill_manual(values = alpha(c("deepskyblue", "indianred"), 1))+
  labs(title = 'Mean Valence Rating for Blue v. Red Pictures',
```

```r
       y = 'Mean Picture Valence Rating',
       x = 'Picture Type') +
  theme_minimal()
valence.violin
```


```r
# ANOVA with color and context as between-subjects factors conducted on valence.

# for color
interact.val.color = aov(data= color_data_pr, Pic_valence_MEAN ~ pic * color)
summary(interact.val.color)
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## pic            1 310.48  310.48 321.005 <2e-16 ***
## color          1   5.17    5.17   5.345 0.0215 *
## pic:color      1   3.98    3.98   4.119 0.0433 *
## Residuals    301 291.13    0.97
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# for context
(interact.val.pic = summary(aov(data= color_data_pr, Pic_valence_MEAN ~ color * pic)))
```

```
##               Df Sum Sq Mean Sq F value Pr(>F)
## color          1   2.67    2.67   2.763 0.0975 .
## pic            1 312.98  312.98 323.587 <2e-16 ***
## color:pic      1   3.98    3.98   4.119 0.0433 *
## Residuals    301 291.13    0.97
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Test-relevant images were generally rated higher in valence (rated as unpleasant) than neutral pictures (main effect of **context**: $F(1,301) = 323.59$, $p < 0.001$). And red pictures generally rated higher in valence than blue pictures (main effect of **color**: $F(1,301) = 5.345$, $p = 0.02$). The main effects were modulated by a significant two-way interaction between color and context (interaction: ($F(1,301) = 4.12$, $p = 0.043$))

Note, the F-statistic for main effect of **context** ($F(1,301) = 323.59$, $p < 0.001$). slightly differs from the reported one ($F(1,301) = 325.48$, $p < 0.001$).

Note, the F-statistic for main effect of **color** ($F(1,301) = 5.345$, $p = 0.02$) slightly differs from the reported one ($F(1,301) = 5.40$, $p = 0.02$).

In conlcustion, valence ratings were larger in the test condition, which is to be expected since the test images were chosen from a database of rated images for their negative valence qualities.

Post Hoc Test

Sheffe Post Hoc Test for multiple comparisons.

```
# scheffe Post Hoc Test Replication
(schef <- PostHocTest(x=interact.val.color, method="scheffe"))
```

```
##
##   Posthoc multiple comparisons of means : Scheffe Test
##     95% family-wise confidence level
##
## $pic
##              diff   lwr.ci   upr.ci   pval
## test-neu 2.017899 1.701262 2.334536 <2e-16 ***
##
## $color
##               diff      lwr.ci    upr.ci   pval
## red-blue 0.2603203 -0.05645299 0.5770936 0.1511
##
## $`pic:color`
##                           diff      lwr.ci     upr.ci   pval
## test:blue-neu:blue  1.80531189  1.36376193  2.2468619 <2e-16 ***
## neu:red-neu:blue    0.03306562 -0.41400166  0.4801329 0.9976
## test:red-neu:blue   2.29605263  1.83969846  2.7524068 <2e-16 ***
## neu:red-test:blue  -1.77224627 -2.21231449 -1.3321781 <2e-16 ***
## test:red-test:blue  0.49074074  0.04124101  0.9402405 0.0257 *
## test:red-neu:red    2.26298701  1.80806636  2.7179077 <2e-16 ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The authors chose to report the results for the comparison between the test:red interaction and the test:blue interaction **(diff 0.491, $p = 0.0257$)**, in order to support the claim that the color red enhances valence perceptions. This, by itself, does not seem to support that particular claim. It does suggest that there is a slight bias for individuals to perceive an affectively charged context as unpleasant if red is present, rather than blue. Another test may be to evaluate whether the test:blue - neu:blue comparison **(diff 1.805, $p < 0.001$)** is significantly different from test:red - neu:red **(diff 2.263, $p < 0.001$)**.

```
(schef <- PostHocTest(x=interact.aro.color, method="scheffe"))
```

```
##
```

```
##   Posthoc multiple comparisons of means : Scheffe Test
##     95% family-wise confidence level
##
## $pic
##              diff   lwr.ci   upr.ci   pval
## test-neu 1.150757 0.847225 1.454289 <2e-16 ***
##
## $color
##              diff      lwr.ci    upr.ci   pval
## red-blue 0.224739 -0.07892334 0.5284014 0.2303
##
## $`pic:color`
##                          diff      lwr.ci     upr.ci    pval
## test:blue-neu:blue  1.0488548  0.62558010  1.4721295 8.9e-10 ***
## neu:red-neu:blue    0.1122266 -0.31633705  0.5407902  0.9095
## test:red-neu:blue   1.3879262  0.95046008  1.8253924 3.0e-15 ***
## neu:red-test:blue  -0.9366282 -1.35848245 -0.5147739 5.3e-08 ***
## test:red-test:blue  0.3390715 -0.09182395  0.7699669  0.1821
## test:red-neu:red    1.2756997  0.83960768  1.7117916 3.4e-13 ***
##
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

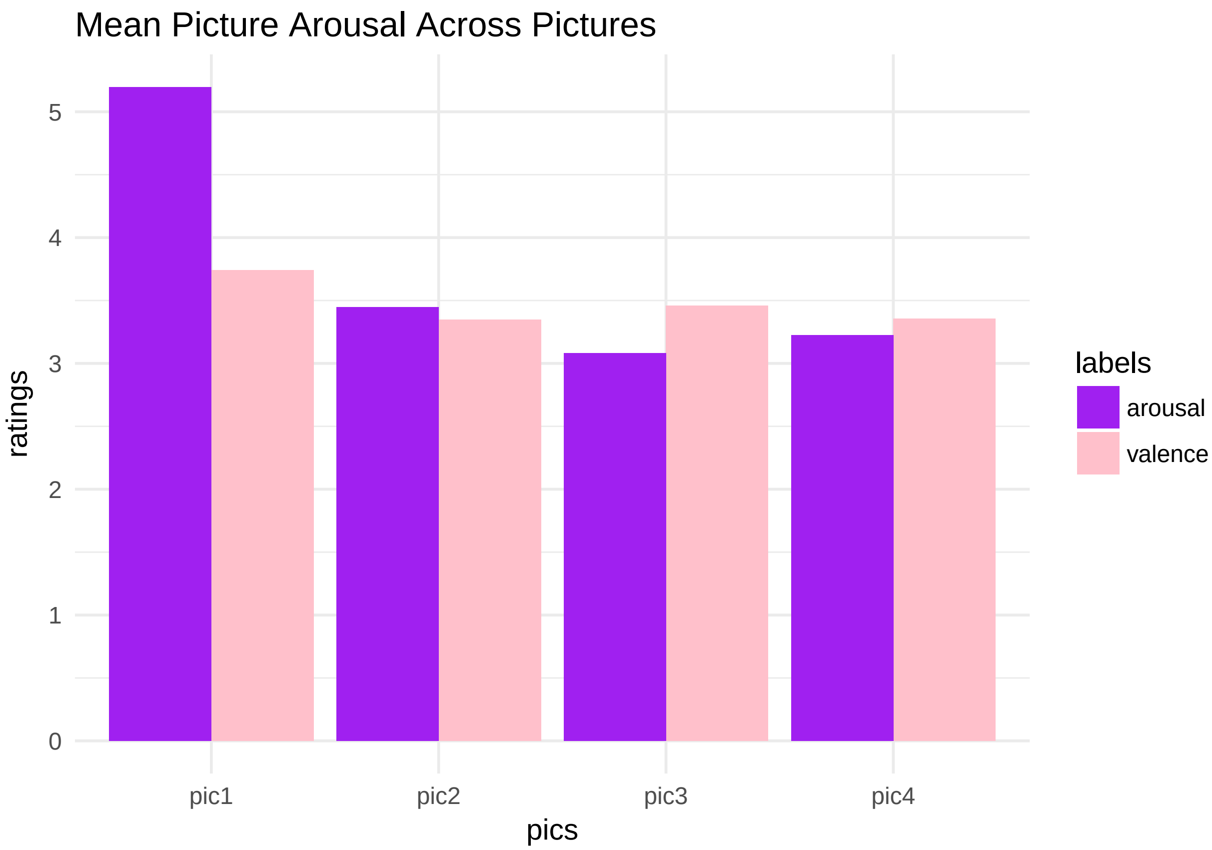
Authors did not include a Scheffe post hoc test on the modulation of **arousal** ratings as a function of color:context interactions. Interestingly, none of the comparisons result in significant values, other than the ones that involve context (e.g. test:blue - neu:blue, test:red-neu:red).

Further Investigation of the Stimuli

Order Effects Investingating further, we decided to look at the arousal and valence reports for each picture individually. We split arousal and valence ratings by image, specifically by the order in the which the images appeared. Note that the figure displays ratings collapsed across conditions.

```
### Odering effects of images.

# bar plots for the distribution of arousal and valence judgements for each picture
arousal_by_pic = c(mean(color_data_pr$pic1_arousal),
                   mean(color_data_pr$pic2_arousal),
                   mean(color_data_pr$pic3_arousal),
                   mean(color_data_pr$pic4_arousal))

valence_by_pic = c(mean(color_data_pr$pic1_valence), mean(color_data_pr$pic2_valence), mean(color_data_p

pics = c('pic1', 'pic2', 'pic3', 'pic4','pic1', 'pic2', 'pic3', 'pic4')
new.df = data.frame(arousal_by_pic, valence_by_pic, pics)

labels = c('arousal', 'arousal', 'arousal', 'arousal',
           'valence', 'valence', 'valence', 'valence')

ratings = c(arousal_by_pic, valence_by_pic)
new.df2 = data.frame(ratings, pics, labels)

arousal.across.pics <- ggplot(new.df2, aes(x=pics, ratings, fill=labels)) +
  geom_bar(stat="identity", position="dodge") +
```

```r
  scale_fill_manual(values = alpha(c("purple", "pink"), 1))+
 labs(title = 'Mean Picture Arousal Across Pictures') +
  theme_minimal()
arousal.across.pics
```

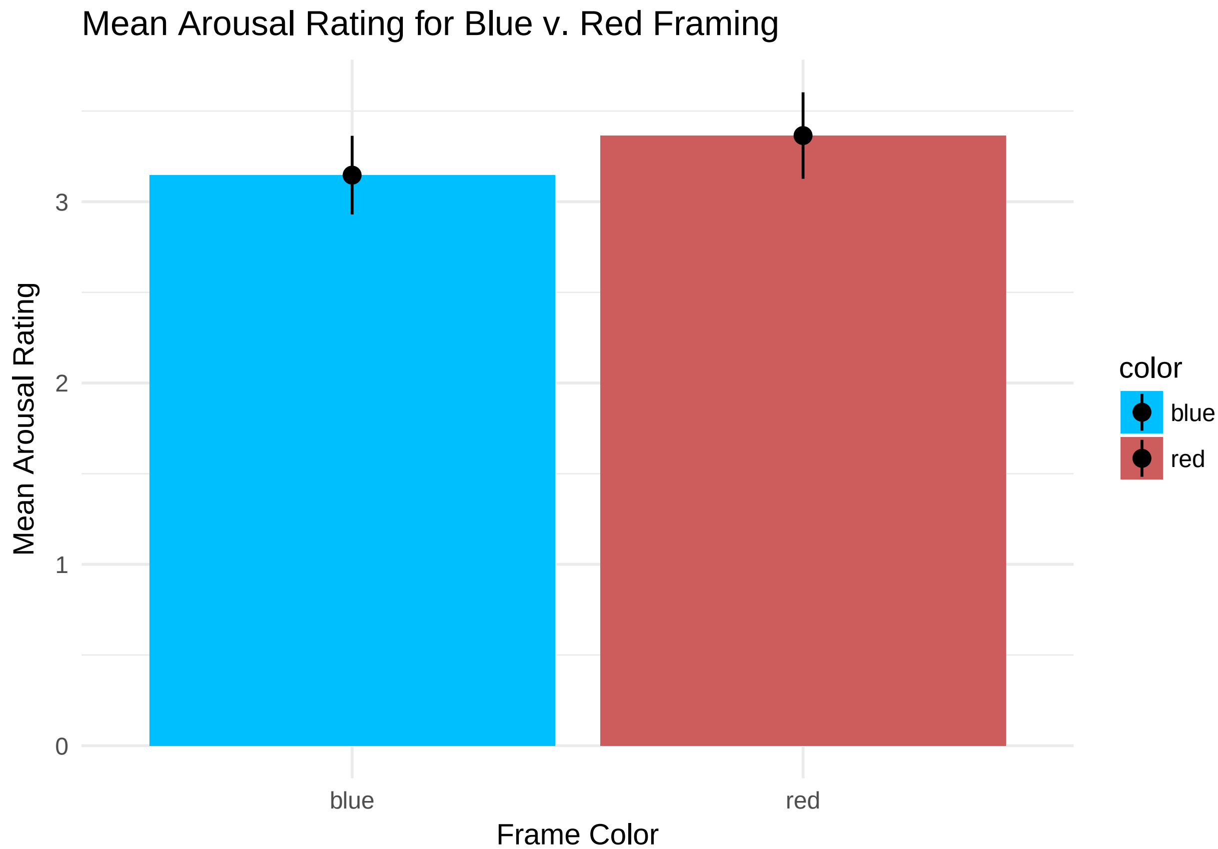


We found that the first image participants see is on average rated higher in arousal compared to the next three images they see. As the authors did not report data by item in their dataframe, we are unable to see if there are any item-based effects in arousal.

However, we decided to further investigate a potential confound of the first image being more arousing due to it being the first in the sequence by removing it from analysis. By removing the first picture, we can see if the author's results are still significant.

```r
# create new, simple dataframe and compure arousal means by subject (without pic1)
new.aro.df <- data.frame(color=color_data_pr$color,
                         pic=color_data_pr$pic,
                         pic2_aro=color_data_pr$pic2_arousal,
                         pic3_aro=color_data_pr$pic3_arousal,
                         pic4_aro=color_data_pr$pic4_arousal)
new.aro.df$aro.mean <- apply(new.aro.df[,3:5], 1, mean)

# Like Figure 1, but without data from "Pic1" included
fig1.nopic1 <- ggplot(new.aro.df, aes(x=color, aro.mean, fill=color))+
  geom_bar(stat="summary", fun.y="mean", position="dodge")+
  scale_fill_manual(values = alpha(c("deepskyblue", "indianred"), 1))+
    stat_summary(fun.y = function(x){mean(x)},
               fun.ymin = function(x){mean(x) - 2*sd(x)/sqrt(length(x))},
               fun.ymax = function(x){mean(x) + 2*sd(x)/sqrt(length(x))},
```

```
                geom= 'pointrange') +
  labs(title = 'Mean Arousal Rating for Blue v. Red Framing',
       y = 'Mean Arousal Rating',
       x = 'Frame Color')+
  theme_minimal()
fig1.nopic1
```




```
interact.new.aro.pic = anova(lm(data = new.aro.df, aro.mean ~ color*pic))
interact.new.aro.pic
```

```
## Analysis of Variance Table
##
## Response: aro.mean
##              Df Sum Sq Mean Sq  F value Pr(>F)
## color         1   3.63   3.633   2.5980 0.1080
## pic           1 175.37 175.372 125.4194 <2e-16 ***
## color:pic     1   1.00   1.004   0.7181 0.3974
## Residuals 301 420.88   1.398
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
interact.new.aro.col = anova(lm(data = new.aro.df, aro.mean ~ pic*color))
interact.new.aro.col
```

```
## Analysis of Variance Table
##
## Response: aro.mean
##              Df Sum Sq Mean Sq  F value  Pr(>F)
```

```
## pic         1 173.32 173.323 123.9534 < 2e-16 ***
## color       1   5.68   5.683   4.0640 0.04469 *
## pic:color   1   1.00   1.004   0.7181 0.39743
## Residuals 301 420.88   1.398
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Even after removing the data collected from first picture ratings, we find that arousal ratings are still higher for red framed pictures. We re-ran the ANOVAS and found a main effect of context ($F(1,301) = 125$, $p < 0.001$) and a main effect of colour ($F(1,301) = 4.06$, $p = 0.0447$). There was no significant interaction of colour and context.

Potential Confounds from Subject Anxiety

Effects of Test Anxiety and General Anxiety on Arousal and Valence Ratings

Valence ANCOVAS

A two-way ANCOVA was conducted with valence ratings as the response variable and colour and context as predictors, whilst controlling for trait anxiety.

```
# ANCOVA with valence rating as the response variable, trait anxiety as control

ancova.val.trait_anxiety1 = anova(lm(data = color_data_pr, Pic_valence_MEAN ~ STAI_MEAN + color*pic))
ancova.val.trait_anxiety1
```

```
## Analysis of Variance Table
##
## Response: Pic_valence_MEAN
##            Df Sum Sq Mean Sq  F value    Pr(>F)
## STAI_MEAN   1   6.02    6.02   6.7636  0.009768 **
## color       1   2.10    2.10   2.3604  0.125510
## pic         1 326.97  326.97 367.2504 < 2.2e-16 ***
## color:pic   1   4.22    4.22   4.7427  0.030206 *
## Residuals 298 265.32    0.89
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
ancova.val.trait_anxiety2 = anova(lm(data = color_data_pr, Pic_valence_MEAN ~ STAI_MEAN + pic*color))
ancova.val.trait_anxiety2
```

```
## Analysis of Variance Table
##
## Response: Pic_valence_MEAN
##            Df Sum Sq Mean Sq  F value    Pr(>F)
## STAI_MEAN   1   6.02    6.02   6.7636  0.009768 **
## pic         1 324.74  324.74 364.7424 < 2.2e-16 ***
## color       1   4.33    4.33   4.8684  0.028115 *
## pic:color   1   4.22    4.22   4.7427  0.030206 *
## Residuals 298 265.32    0.89
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

There was a significant difference in valence rating with context added to the model ($F(1,298)=367.25$, $p < 0.001$). When colour was added to the model with trait anxiety controlled, there was a significant main effect

(F(1,298)=4.8684, p = 0.028115). There was an interaction effect of colour and context (F(1,298)= 4.7427, p = 0.030206).

Next, two-way ANCOVA was conducted with valence ratings as the response variable and colour and context as predictors, whilst controlling for test anxiety.

```
# ANCOVA with valence rating as the response variable, test anxiety as control

ancova.val.test_anxiety1 = anova(lm(data = color_data_pr, Pic_valence_MEAN ~ AEQanxiety_MEAN + color*pic
ancova.val.test_anxiety1
```

```
## Analysis of Variance Table
##
## Response: Pic_valence_MEAN
##                  Df  Sum Sq Mean Sq  F value    Pr(>F)
## AEQanxiety_MEAN   1  24.959  24.959  28.1031 2.234e-07 ***
## color             1   0.578   0.578   0.6511   0.42036
## pic               1 315.974 315.974 355.7771 < 2.2e-16 ***
## color:pic         1   2.817   2.817   3.1719   0.07593 .
## Residuals       300 266.437   0.888
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
ancova.val.test_anxiety2 = anova(lm(data = color_data_pr, Pic_valence_MEAN ~ AEQanxiety_MEAN + pic*color
ancova.val.test_anxiety2
```

```
## Analysis of Variance Table
##
## Response: Pic_valence_MEAN
##                  Df  Sum Sq Mean Sq  F value    Pr(>F)
## AEQanxiety_MEAN   1  24.959  24.959  28.1031 2.234e-07 ***
## pic               1 314.759 314.759 354.4090 < 2.2e-16 ***
## color             1   1.793   1.793   2.0191   0.15637
## pic:color         1   2.817   2.817   3.1719   0.07593 .
## Residuals       300 266.437   0.888
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

There was a significant difference in valence rating with context added to the model (F(1,300)=355.78, p < 0.001). When colour was added to the model with test anxiety controlled, there was no longer a significant main effect for colour (F(1,300)=2.0191, p = 0.15637). There was no interaction effect of colour and context (F(1,300)= 3.1719, p = 0.07593).

Arousal ANCOVAS

A two-way ANCOVA was conducted with arousal ratings as the response variable and colour and context as predictors, whilst controlling for trait anxiety.

```
# ANCOVA with arousal rating as the response variable, trait anxiety as control

ancova.aro.trait_anxiety1 = anova(lm(data = color_data_pr, Pic_arousal_MEAN ~ STAI_MEAN + color*pic))
ancova.aro.trait_anxiety1
```

```
## Analysis of Variance Table
##
## Response: Pic_arousal_MEAN
```

```
##            Df  Sum Sq Mean Sq  F value    Pr(>F)
## STAI_MEAN   1   7.162   7.162   8.3929  0.004046 **
## color       1   1.788   1.788   2.0952  0.148818
## pic         1 108.184 108.184 126.7686 < 2.2e-16 ***
## color:pic   1   1.284   1.284   1.5045  0.220951
## Residuals 298 254.311   0.853
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
ancova.aro.trait_anxiety2 = anova(lm(data = color_data_pr, Pic_arousal_MEAN ~ STAI_MEAN + pic*color))
ancova.aro.trait_anxiety2
```

```
## Analysis of Variance Table
##
## Response: Pic_arousal_MEAN
##            Df  Sum Sq Mean Sq  F value    Pr(>F)
## STAI_MEAN   1   7.162   7.162   8.3929  0.004046 **
## pic         1 107.080 107.080 125.4752 < 2.2e-16 ***
## color       1   2.892   2.892   3.3886  0.066642 .
## pic:color   1   1.284   1.284   1.5045  0.220951
## Residuals 298 254.311   0.853
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

There was a significant difference in arousal rating with context added to the model ($F(1,298)=126.766$, $p < 0.001$). When colour was added to the model with trait anxiety controlled, there was a significant main effect ($F(1,298)=3.3886$, $p = 0.06664$). There was no interaction effect of colour and context ($F(1,298) = 1.5045$, $p =0.220951$).

A two-way ANCOVA was conducted with arousal ratings as the response variable and colour and context as predictors, whilst controlling for test anxiety.

```r
# ANCOVA with arousal rating as the response variable, test anxiety as control

ancova.aro.test_anxiety1 = anova(lm(data = color_data_pr, Pic_arousal_MEAN ~ AEQanxiety_MEAN + color*pic
ancova.aro.test_anxiety1
```

```
## Analysis of Variance Table
##
## Response: Pic_arousal_MEAN
##                  Df  Sum Sq Mean Sq  F value    Pr(>F)
## AEQanxiety_MEAN   1  25.943  25.943  32.1018  3.43e-08 ***
## color             1   0.498   0.498   0.6161    0.4331
## pic               1 104.002 104.002 128.6925 < 2.2e-16 ***
## color:pic         1   0.451   0.451   0.5575    0.4559
## Residuals       300 242.442   0.808
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
ancova.aro.test_anxiety2 = anova(lm(data = color_data_pr, Pic_arousal_MEAN ~ AEQanxiety_MEAN + pic*colo
ancova.aro.test_anxiety2
```

```
## Analysis of Variance Table
##
## Response: Pic_arousal_MEAN
##                  Df  Sum Sq Mean Sq  F value    Pr(>F)
## AEQanxiety_MEAN   1  25.943  25.943  32.1018  3.43e-08 ***
```

```
## pic                1 103.423 103.423 127.9767 < 2.2e-16 ***
## color              1   1.076   1.076   1.3319    0.2494
## pic:color          1   0.451   0.451   0.5575    0.4559
## Residuals        300 242.442   0.808
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

There was a significant difference in valence rating with context added to the model (F(1,300)=128.69, $p < 0.001$). When colour was added to the model with trait anxiety controlled, there was a significant main effect (F(1,300)=1.3319, $p = 0.2494$). There was no interaction effect of colour and context (F(1,300) = 0.5575, $p = 0.4559$).

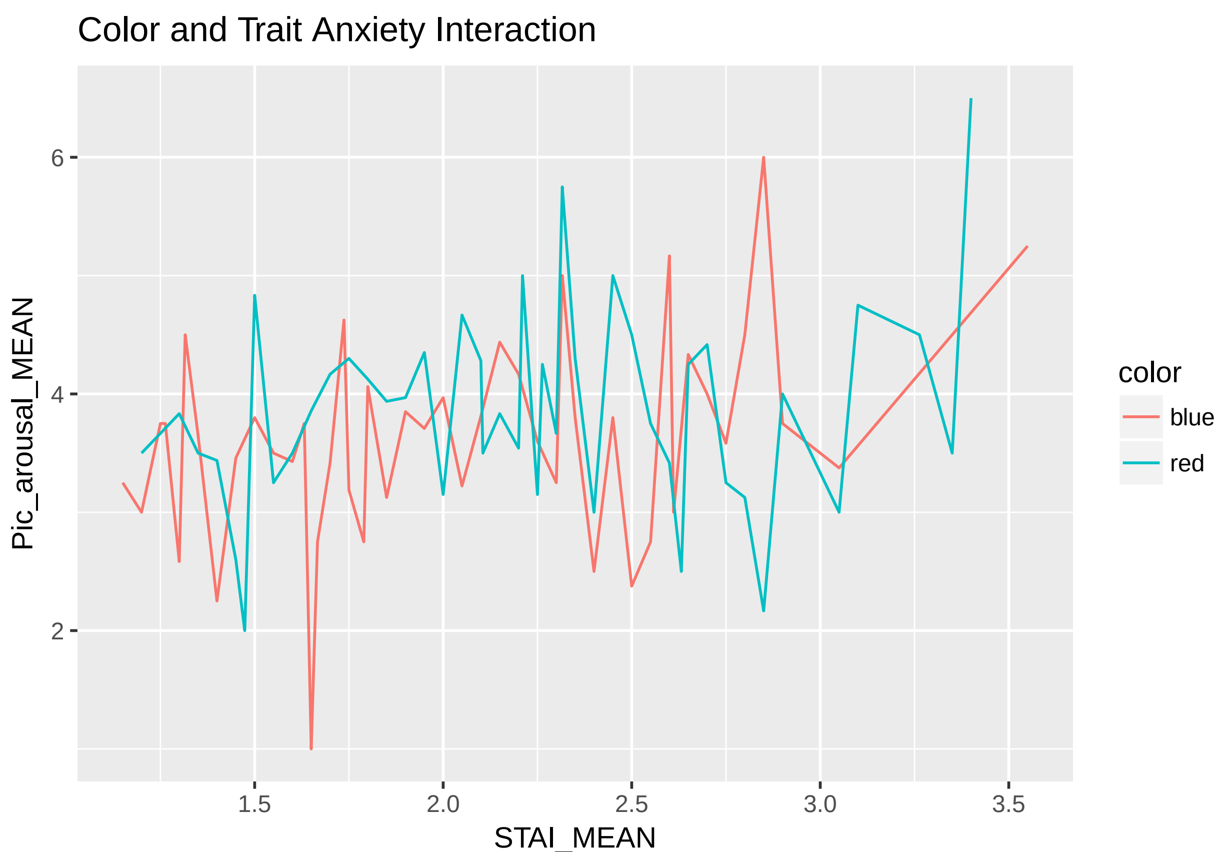
In the paper, the authors state that they performed supplementary analyses controlling for both trait and test anxiety, and that the tests showed that anxiety did not substantially moderate the interaction effect on valence reported above. We confirmed this for trait anxiety, but not for test anxiety. They did not report the results of an ANCOVA of arousal ratings with anxiety as a covariate.

Anxiety Interaction Graphs

```
# anova: interaction between color and Trait anxiety
summary(aov(Pic_arousal_MEAN ~ color * STAI_MEAN, data=color_data_pr))
```

```
##                  Df Sum Sq Mean Sq F value Pr(>F)
## color             1    2.4   2.397   1.977 0.1608
## STAI_MEAN         1    6.6   6.553   5.404 0.0208 *
## color:STAI_MEAN   1    1.2   1.199   0.989 0.3209
## Residuals       299  362.6   1.213
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 2 observations deleted due to missingness
```

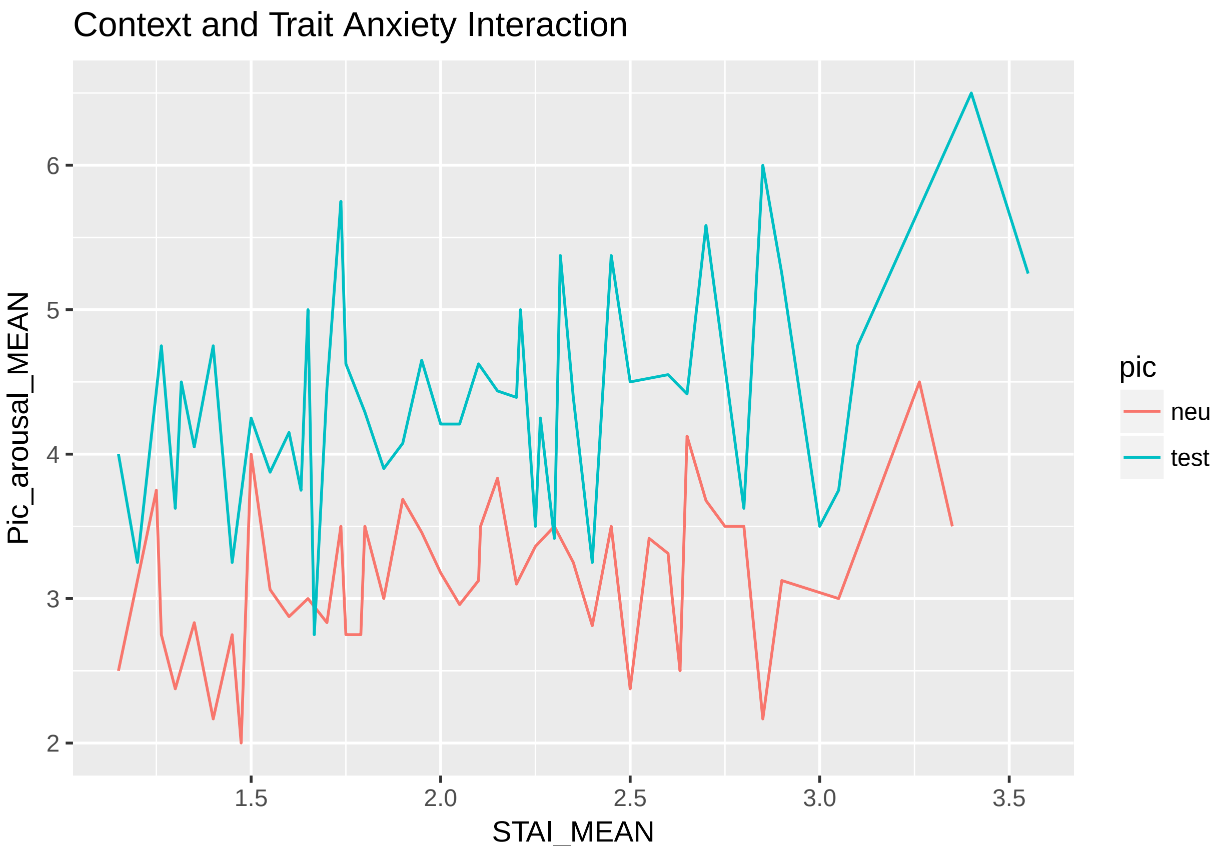
```
# Plot: interaction between color and Trait anxiety
trait.anxiety.interaction <- color_data_pr %>%
  ggplot() +
  aes(x = STAI_MEAN, color = color, group = color, y = Pic_arousal_MEAN) +
  stat_summary(fun.y = mean, geom = "line")+ ggtitle('Color and Trait Anxiety Interaction')
trait.anxiety.interaction
```




```
# anova: interaction between context and Trait anxiety
summary(aov(Pic_arousal_MEAN ~ pic * STAI_MEAN, data=color_data_pr))
```

```
##                  Df Sum Sq Mean Sq F value   Pr(>F)
## pic               1 100.51  100.51 116.646  < 2e-16 ***
## STAI_MEAN         1  13.74   13.74  15.941 8.23e-05 ***
## pic:STAI_MEAN     1   0.86    0.86   0.996    0.319
## Residuals       299 257.63    0.86
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 2 observations deleted due to missingness
```

```
# Plot: interaction between context and Trait anxiety
context.traitAnx.interact<- color_data_pr %>%
  ggplot() +
  aes(x = STAI_MEAN, color = pic, group = pic, y = Pic_arousal_MEAN) +
  stat_summary(fun.y = mean, geom = "line")+ ggtitle('Context and Trait Anxiety Interaction')
context.traitAnx.interact
```




```r
# anova: interaction between color and Test anxiety
summary(aov(Pic_arousal_MEAN ~ color * AEQanxiety_MEAN, data=color_data_pr))
```

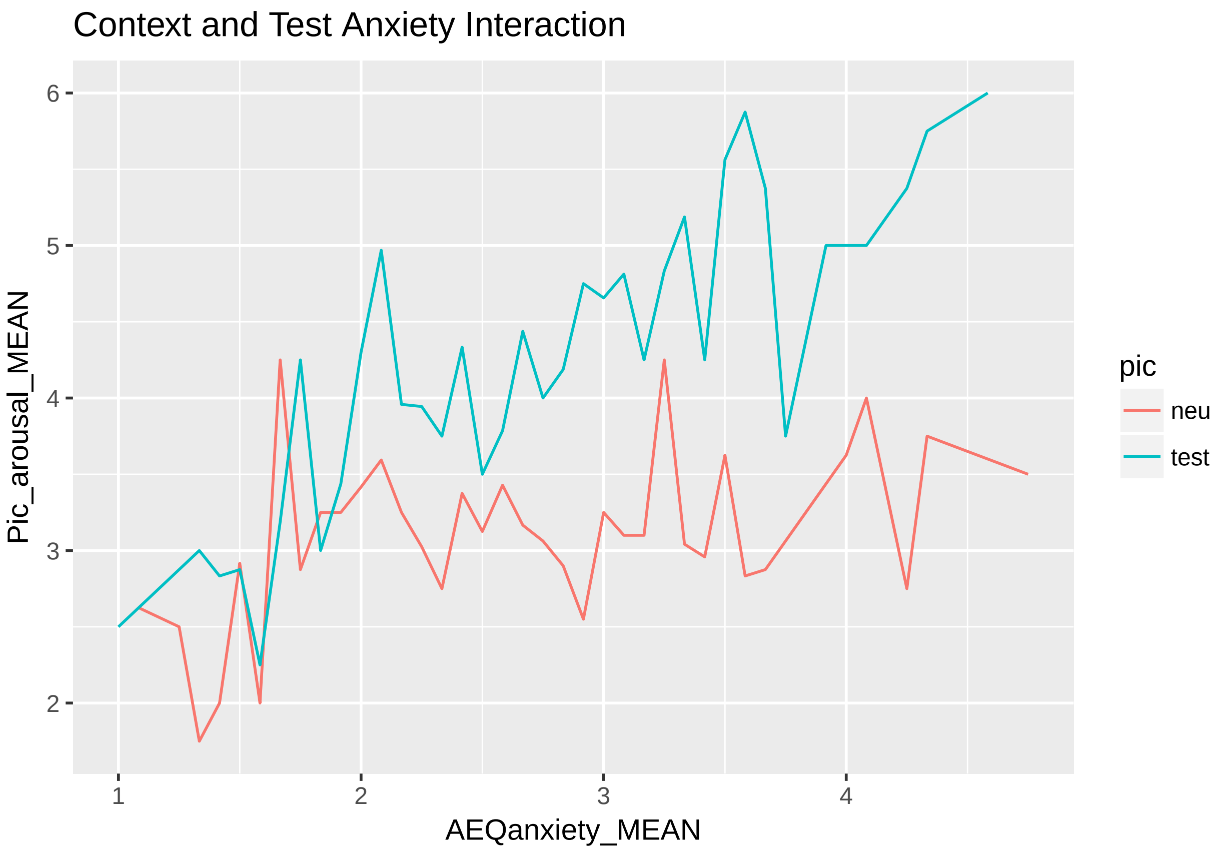
```
##                       Df Sum Sq Mean Sq F value   Pr(>F)    
## color                  1    2.6   2.554   2.216    0.138    
## AEQanxiety_MEAN        1   23.9  23.887  20.732 7.68e-06 ***
## color:AEQanxiety_MEAN  1    0.1   0.083   0.072    0.788    
## Residuals            301  346.8   1.152                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Plot: interaction between color and Test anxiety
color.testAnx.interact <- color_data_pr %>%
  ggplot() +
  aes(x = AEQanxiety_MEAN, color = color, group = color, y = Pic_arousal_MEAN) +
  stat_summary(fun.y = mean, geom = "line")+
  ggtitle('Color and Test Anxiety Interaction')

color.testAnx.interact
```


```r
# anova: interaction between context and Test anxiety
summary(aov(Pic_arousal_MEAN ~ pic * AEQanxiety_MEAN, data=color_data_pr))
```

```
##                       Df Sum Sq Mean Sq F value   Pr(>F)    
## pic                    1 100.97  100.97  132.72  < 2e-16 ***
## AEQanxiety_MEAN        1  28.39   28.39   37.32 3.09e-09 ***
## pic:AEQanxiety_MEAN    1  14.98   14.98   19.69 1.28e-05 ***
## Residuals            301 228.99    0.76                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# Plot: interaction between context and Test anxiety
context.testAnx.interact<- color_data_pr %>%
  ggplot() +
  aes(x = AEQanxiety_MEAN, color = pic, group = pic, y = Pic_arousal_MEAN) +
  stat_summary(fun.y = mean, geom = "line")+ ggtitle('Context and Test Anxiety Interaction')
context.testAnx.interact
```



There is no interaction for the first three graphs. However the last one shows that there is a strong interaction between Test anxiety and context. $F(1,301) = 19.69$ $p < .001$

```
# controling for test anxiety on context.

summary(aov(Pic_arousal_MEAN ~ STAI_MEAN + pic, data=color_data_pr))
```

```
##                Df Sum Sq Mean Sq F value  Pr(>F)
## STAI_MEAN       1   7.16    7.16   8.313 0.00422 **
## pic             1 107.08  107.08 124.277 < 2e-16 ***
## Residuals     300 258.49    0.86
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 2 observations deleted due to missingness
```

However, when controling for Test anxiety, context was still significant. $F(1,300) = 124$ $p<.001$

```
### How about for Valence
# anova: interaction between color and Trait anxiety
summary(aov(Pic_valence_MEAN ~ color * STAI_MEAN, data=color_data_pr))
```

```
##                    Df Sum Sq Mean Sq F value Pr(>F)
## color               1    2.7   2.698   1.366 0.2434
## STAI_MEAN           1    5.4   5.426   2.748 0.0984 .
## color:STAI_MEAN     1    6.1   6.142   3.111 0.0788 .
## Residuals         299  590.4   1.974
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 2 observations deleted due to missingness
```

```r
# anova: interaction between context and Trait anxiety
summary(aov(Pic_valence_MEAN ~ pic * STAI_MEAN, data=color_data_pr))
```

```
##                Df Sum Sq Mean Sq F value   Pr(>F)    
## pic             1 312.63  312.63 343.871  < 2e-16 ***
## STAI_MEAN       1  18.14   18.14  19.949 1.13e-05 ***
## pic:STAI_MEAN   1   2.04    2.04   2.247    0.135    
## Residuals     299 271.83    0.91                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 2 observations deleted due to missingness
```

```r
# anova: interaction between color and Test anxiety
summary(aov(Pic_valence_MEAN ~ color * AEQanxiety_MEAN, data=color_data_pr))
```

```
##                        Df Sum Sq Mean Sq F value   Pr(>F)    
## color                   1    2.7   2.672   1.374 0.241975    
## AEQanxiety_MEAN         1   22.9  22.865  11.761 0.000689 ***
## color:AEQanxiety_MEAN   1    0.0   0.030   0.015 0.901819    
## Residuals             301  585.2   1.944                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```r
# anova: interaction between context and Test anxiety
summary(aov(Pic_valence_MEAN ~ pic * AEQanxiety_MEAN, data=color_data_pr))
```

```
##                      Df Sum Sq Mean Sq F value   Pr(>F)    
## pic                   1 310.48  310.48  370.01  < 2e-16 ***
## AEQanxiety_MEAN       1  29.24   29.24   34.84 9.62e-09 ***
## pic:AEQanxiety_MEAN   1  18.47   18.47   22.02 4.11e-06 ***
## Residuals           301 252.57    0.84                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

There is a strong interaction between Test anxiety and Context. $F(1,301)=22.01$ $p<.001$.

Lets do an ANCOVA to look for the effects of context after test anxiety is acounted for.

```r
summary(aov(Pic_valence_MEAN ~ AEQanxiety_MEAN + pic, data=color_data_pr))
```

```
##                  Df Sum Sq Mean Sq F value   Pr(>F)    
## AEQanxiety_MEAN   1  24.96   24.96   27.81 2.56e-07 ***
## pic               1 314.76  314.76  350.70  < 2e-16 ***
## Residuals       302 271.05    0.90                     
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

The effect of context on valence is still significant. $F(1,302) = 350$, $P < .001$