STATISTICAL METHODS IN RESEARCH

Analysis of How Stress Patterns Define Human Experience and Performance in Dexterous Tasks

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INTRODUCTION

The Microsurgery performance data represents the performance of 22 medical students in microsurgery activities. The 22 medical students or subjects in our analysis, participated in a longitudinal study regarding the relationship of sympathetic arousal and skill in learning microsurgical tasks. The subjects had to pay five visits which we regard as sessions, lasting one hour each, in order to practice micro-surgical cutting and suturing in an inanimate simulator.A pre and post study questionnaire was also given to be completed by the subjects to know a little about their biography and anxiety.

During the main part of each session, the subjects underwent the following treatments:
1.Baseline: The subjects were relaxing for 5 min, listening to spa music. They were facially recorded by a thermal and visual camera.
2.Cutting: The subjects had to precision cutting in the inanimate simulator. They were facially recorded by a thermal and visual camera.
3.Suturing: The subjects had to perform suturing in the inanimate simulator. They were facially recorded by a thermal and visual camera.

Explicit accuracy scores per task is provided in the data. Hence, the cutting task has its own accuracy scores and so is the case with the suturing task. The perspiration values are recorded in all time frames for all subjects and sessions. The subjects were asked to fill out a NASA-TLX questionnaire after each task. he NASA-TLX instrument features five subscales measuring different aspects of the subjects' perceptions regarding task difficulty.We perform an analysis with this given data.

MOTIVATION

DATA ORGANIZATION

The data was structured into main 3 main files.
1. MicroSurgeryPerformance file :

This file indicates the Age, Sex, Year, Time Taken for Cutting and Suturing in each session, Scores of Cutting and Suturing of both the Scorers in Each Session, Number of Sutures made in each session for each subject.

2. MasterFileMethodistSurgery:

This file indicates the presence and absence of the files of Baseline Perinasal Perspiration(PP), Cutting PP, Suturing PP, Cutting NASA,Suturing NASA, Mbg, and MPOST for each subject and each session.

3. TaiScore.txt:

This file indicates the tai scores of all subjects.

Along with this, there is a folder for each subject.Each Subject folder consists of :

1. Subject_tai.csv : which is a behavior analysis questionnaire.
2. Mbg and Mpost csv files which contain geographic and personal information of the subject before and after the tasks.
3. tp.csv, which gives pre and post Session values.
4.A folder. for each session.

Each Session Folder consists of five files:

1.Baseline.csv: Consists of the values of the Perspiration when the subjects were relaxed. This data is collected over every frame in every second for 5 minutes

2.Cutting.csv: Consists of the values of the Perspiration when the subjects were performing cutting task. This data is collected over every frame during the time taken to complete the task

3.Cutting_NASA.csv: Consists of Responses to the NASA TLX questionnaire.

4.Suturing.csv: Consists of the values of the Perspiration when the subjects were performing Suturing task. This data is collected over every frame during the time taken to complete the task

5.Suturing_NASA.csv: Consist of Responses to the NASA TLX questionnaire.

DATA CLEANING

To perform any analysis , we first need to clean the data to removed any redundant data and reshape the data to help us perform any statistical tests.

We perform our data cleaning on the MicroSurgeryPerformance.csv file.
1.For each row, where Sex value is 1 we rename to Male and 2 to Female.
2.We melt the data frame to obtain the Score values pertaining to each subject and each session.
3.We mention the Task to which the Scores belong.
4.With two Scorers being present, we extend the rows of the data to append Score values of the Scorer2.
5. For each subject, for each session and task, we take the Mean_Perspiration(mean persinal perspiration)value as Mean_(task)Perspiration-Mean(Baseline)Perspiration.
This is done because, to get the stress signal caused only by the task can be obtained by
stress signal obtained during task - stress signal during relaxed.

6.We now normalize the Mean_Perspiration values, by taking the absolute minimum value(excluding NA) and adding to each value along with an error coefficient. We add this as Normalised_PP
7.The time taken for each task per session is totally converted into seconds .

The data now has the following format:

	Subject	Age	Year	Sex	Session	Scorer	Task	Scores	Mean_Perspiration	Normalised_PP	Time
1	1	22	1	Male	Session1	Scorer1	Cutting	18	-0.0000159794	0.007539787	595
2	1	22	1	Male	Session2	Scorer1	Cutting	22	0.0011471670	0.008702933	359
3	1	22	1	Male	Session3	Scorer1	Cutting	23	-0.0008589810	0.006696785	487
4	1	22	1	Male	Session4	Scorer1	Cutting	22	NA	NA	153
5	1	22	1	Male	Session5	Scorer1	Cutting	22	NA	NA	245
6	2	23	1	Male	Session1	Scorer1	Cutting	17	-0.0059216820	0.001634084	405

Figure 1: Data Cleaned for Analysis

INITIAL ANALYSIS

Biographic Data

We draw a bar plot to see how gender defines data and histogram to see whether age has any effect on the data.

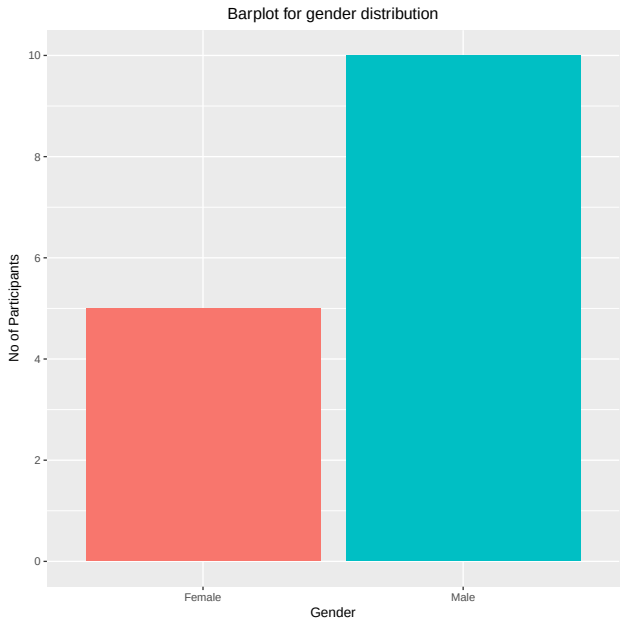

Figure 2: Barplot of Gender Distribution

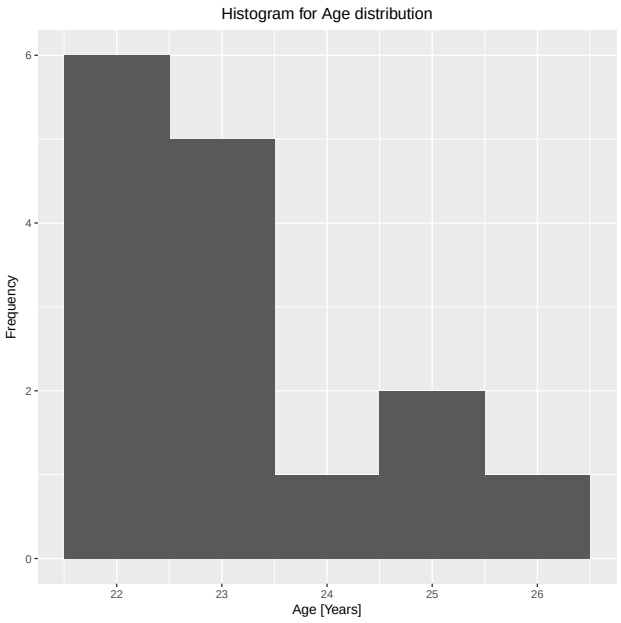

Figure 3: Histogram of age distribution

Trait Psychometric Data

We draw the histogram for Trait Anxiety Inventory(TAI) scores

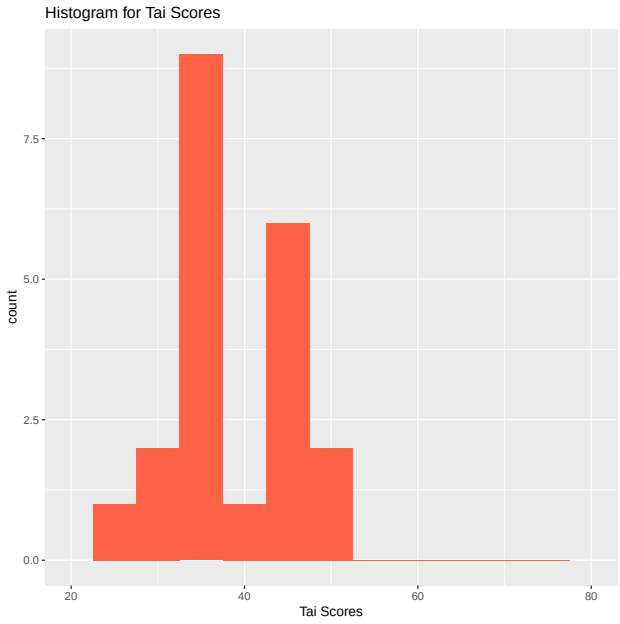

Figure 4: Histogram of Tai Scores

State Psychometric Data

For each subject draw the bar plots for all the NASA-TLX subscales per task. This will give two figures per subject per subscale, one for suturing and one for cutting, where the evolution of the scores from the initial to the final session will be evident.

Perinasal Perspiration (Stress) Signal Data

For each session of each subject we draw the perspiration values using black for baseline, green for cutting, and red for suturing.

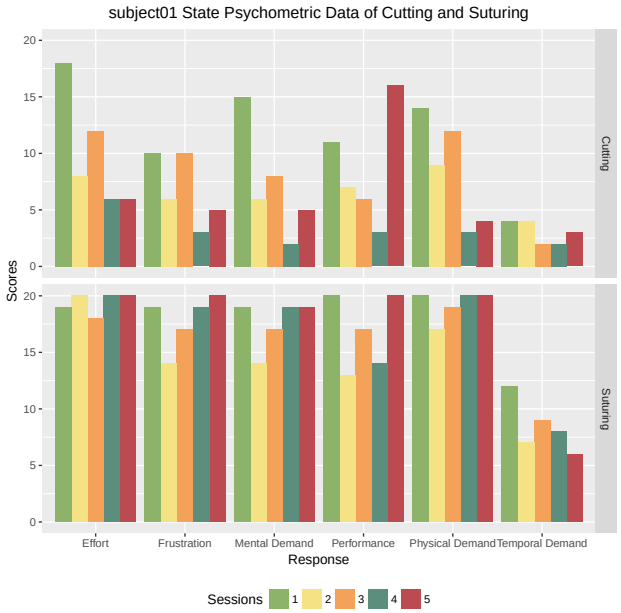

Figure 5: Subject 1

Figure 6: Subject 2

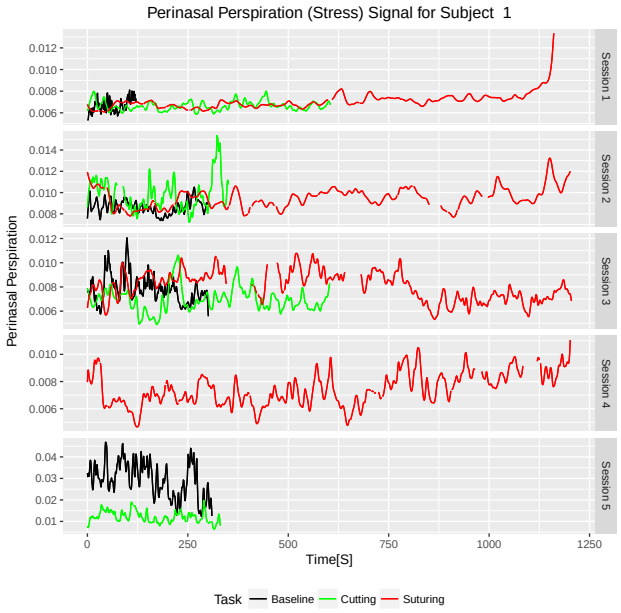

Figure 7: Subject 1

Figure 8: Subject 2

Performance Data

We draw the accuracy and time bar plots of each subject for each session and each task.

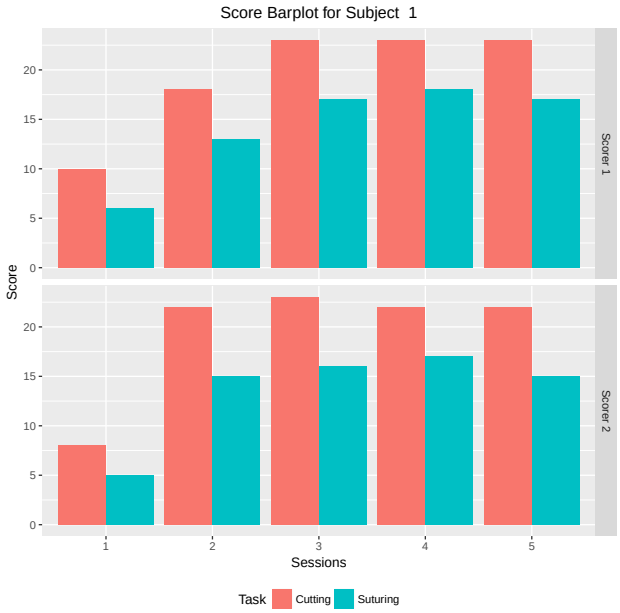

Figure 9: Subject 1 Score Barplot

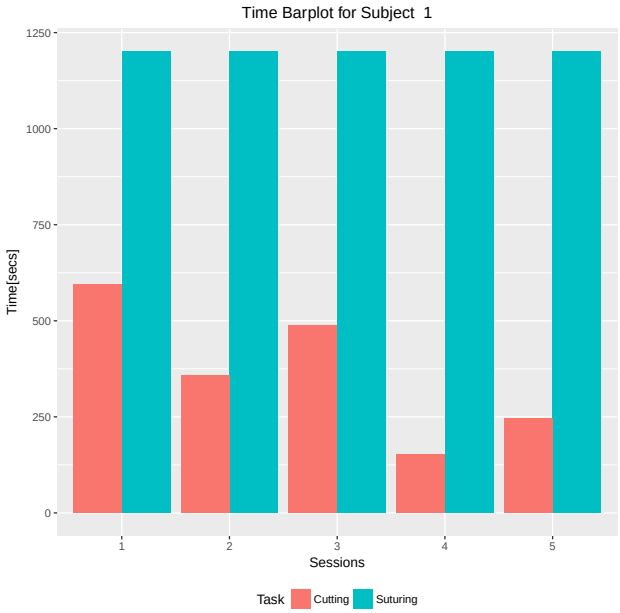

Figure 10: Subject 1 Time Barplot

HYPOTHESIS TESTING

We normalize the perspiration values and perform the log of the values for our analysis.

1. Analysis of effect of each attribute on Score

Hypothesis:
$NullHypothesis$: H_0 = The score obtained does not depend on the demographics of the subject , session , age , year , sex and perspiration.
$AlternateHypothesis$: H_1 = The score obtained depends on the demographics of the subject , session , age , year , sex and perspiration.

Approach:Linear Modelling:
Linear modeling gives the relationship between the dependent and independent variables. In our data set we are finding the hypothesis between each attribute such as Age, sex, year and mean perspiration with the scores of scorer.

Inference:
The above equation informs us that scores will increase by -34.67 for every one percent increase in mean Perspiration value , and score is directly proportional to age which states that the if older age people are hired the score would have increased

```
Call:
lm(formula = Scores ~ log(Normalised_PP) + Age + Sex + Task +
    Scorer + Session, data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-9.0904 -2.0812  0.1778  2.4703  8.4800

Coefficients:
                  Estimate Std. Error t value             Pr(>|t|)
(Intercept)        0.43830    5.71336   0.077              0.93891
log(Normalised_PP) -1.13961    0.74582  -1.528              0.12772
Age                 0.49486    0.17195   2.878              0.00433 **
SexMale            -2.17630    0.47007  -4.630       0.000005768227 ***
TaskSuturing       -0.97517    0.42795  -2.279              0.02349 *
ScorerScorer2       0.02941    0.42648   0.069              0.94507
SessionSession2     4.26300    0.69164   6.164       0.000000000267 ***
SessionSession3     6.38075    0.69130   9.230 < 0.0000000000000002 ***
SessionSession4     7.68358    0.70093  10.962 < 0.0000000000000002 ***
SessionSession5     8.17553    0.71138  11.492 < 0.0000000000000002 ***

Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
---
Residual standard error: 3.517 on 262 degrees of freedom
  (28 observations deleted due to missingness)
Multiple R-squared:  0.4606,    Adjusted R-squared:  0.442
F-statistic: 24.86 on 9 and 262 DF,  p-value: < 0.00000000000000022
```

Figure 11: Linear model of score vs all other attributes

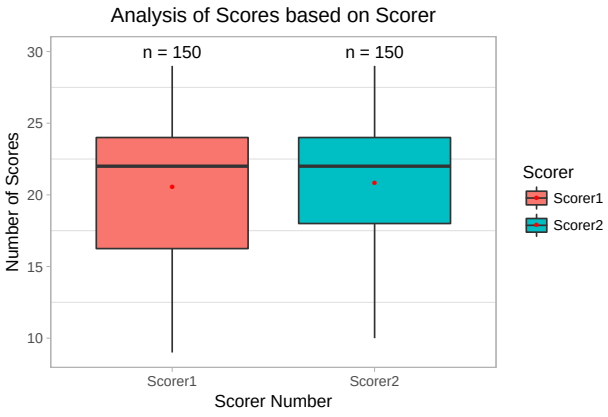

Figure 12: Analysis of Scores based on Score

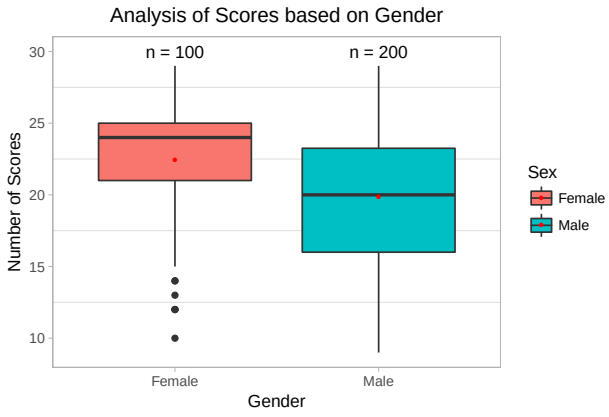

Figure 13: Analysis of Scores based on Gender

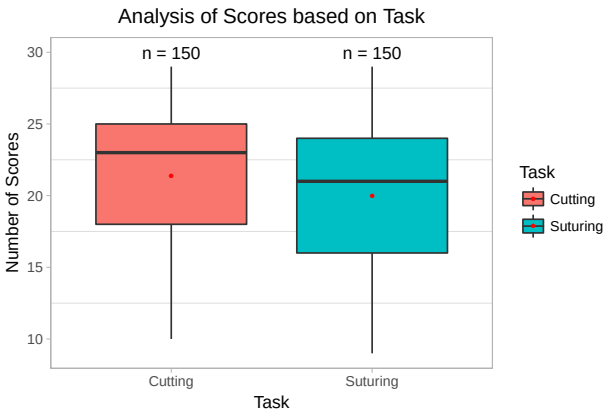

Figure 14: Analysis of Scores based on Task

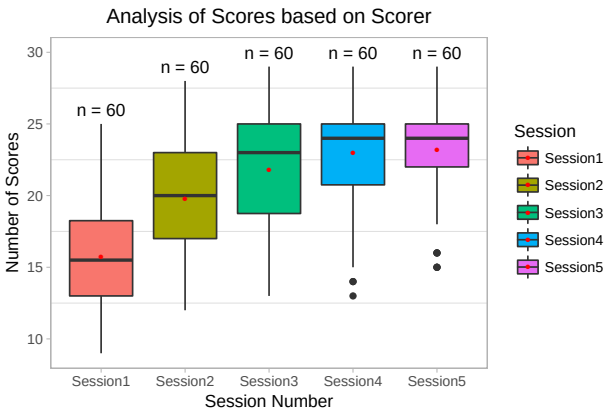

Figure 15: Analysis of Scores based on Session

2. Analysis of effect of each attribute on Time

Hypothesis:

$NullHypothesis$: H_0 = The time taken to do a task is not dependednt of age, session, sex, Perspiration.

$AlternateHypothesis$: H_1 = he time taken to do a task depends on age, session, sex, Perspiration.

Approach:Linear Modelling:

Linear modeling gives the relationship between the dependent and independent variables. In our data set we are finding the hypothesis between each attribute such as Age, sex, year and mean perspiration with the time taken to do the task.

```
Call:
lm(formula = Time ~ log(Normalised_PP) + Age + Sex + Task + Session,
    data = data)

Residuals:
    Min      1Q  Median      3Q     Max
-340.68  -66.10    4.40   78.19  302.39

Coefficients:
                  Estimate Std. Error t value             Pr(>|t|)
(Intercept)         90.273    189.620   0.476                0.634
log(Normalised_PP) -15.595     24.770  -0.630                0.530
Age                  7.915      5.711   1.386                0.167
SexMale             18.922     15.612   1.212                0.227
TaskSuturing       872.331     14.213  61.375 < 0.0000000000000002 ***
SessionSession2   -105.645     22.971  -4.599   0.0000065992793776 ***
SessionSession3   -113.626     22.959  -4.949   0.0000013335710345 ***
SessionSession4   -185.969     23.279  -7.989   0.0000000000000429 ***
SessionSession5   -170.059     23.626  -7.198   0.0000000000064042 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 116.8 on 263 degrees of freedom
  (28 observations deleted due to missingness)
Multiple R-squared:  0.9365,    Adjusted R-squared:  0.9345
F-statistic: 484.7 on 8 and 263 DF,  p-value: < 0.00000000000000022
```

Figure 16: Linear model of Time vs all other attributes

Inference:

We observe that the means of Time vs Scorer or Gender do not have highly significant difference. Although, Task does have significant difference, we do not take it as a notifiable inference, because the time limits are different for each tasks, with time to complete suturing task being. 20 minutes. Hence, From the summary and the plots we infer that the time taken highly depends on the sessions.

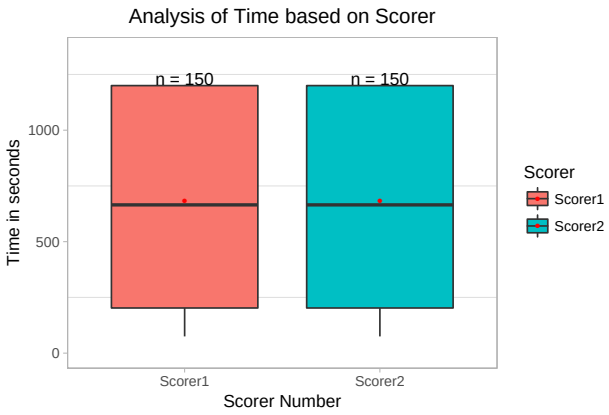

Figure 17: Analysis of Time based on Score

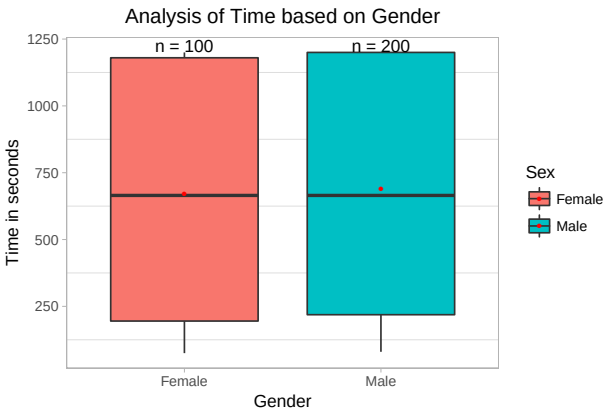

Figure 18: Analysis of Time based on Gender

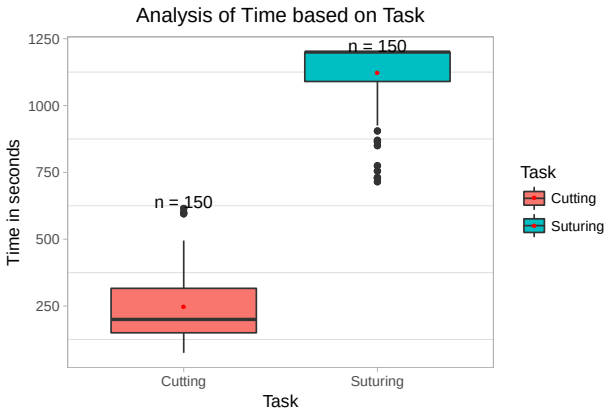

Figure 19: Analysis of Time based on Task

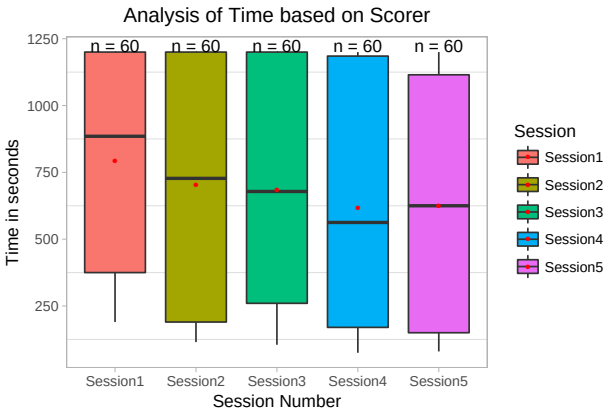

Figure 20: Analysis of Time based on Session

3. Performance Analysis of Suturing Task

Approach:Linear Model:

From the figures, we understand that the number of sutures increases with each session.
To summarize it over all the subjects, we draw the bar plot with values of all subjects summed under each session , which gives us an understanding that with each session, the performance

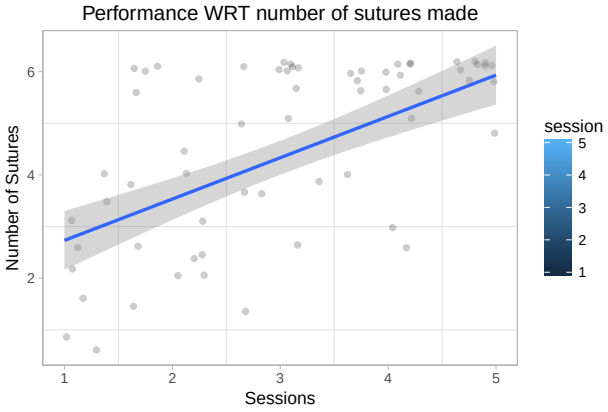

Figure 21: Performance WRT number of sutures made

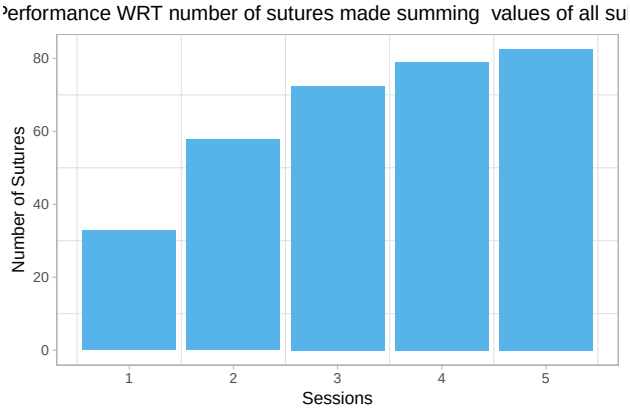

Figure 22: Performance WRT number of sutures summed across all subjects

```
Call:
lm(formula = Sutures ~ Sex * session)

Residuals:
   Min     1Q Median     3Q    Max
 -2.95  -0.70   0.30   0.75   2.80

Coefficients:
                     Estimate Std. Error t value    Pr(>|t|)
(Intercept)             3.2000     0.5732   5.582 0.000000499 ***
SexMale                -1.5000     0.7021  -2.136    0.036409 *
sessionSession2         2.1000     0.8107   2.590    0.011823 *
sessionSession3         2.4000     0.8107   2.960    0.004284 **
sessionSession4         2.5000     0.8107   3.084    0.002999 **
sessionSession5         2.8000     0.8107   3.454    0.000978 ***
SexMale:sessionSession2 -0.6500     0.9929  -0.655    0.515003
SexMale:sessionSession3  0.3500     0.9929   0.353    0.725601
SexMale:sessionSession4  0.8500     0.9929   0.856    0.395098
SexMale:sessionSession5  0.7500     0.9929   0.755    0.452759
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.282 on 65 degrees of freedom
Multiple R-squared:  0.5661,    Adjusted R-squared:  0.5061
F-statistic: 9.425 on 9 and 65 DF,  p-value: 0.000000005144
```

Figure 23: Analysis of Linear Model

increases across all subjects.

When creating the linear model, and performing the analysis, we observe that the number of sutures is highly dependent on sessions . Also, from the Performance analysis with respect to time plot(Figure:23), we infer that as the time decreases, the subjects are able to make more number of sutures and as number of session increases, the performance gets better. **Inference**: The number of sutures made increases with each session and takes less time, i.e the subjects are

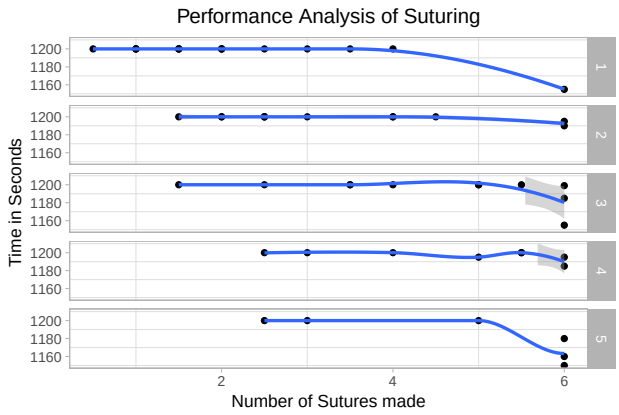

Figure 24: Performance Analysis of Suturing overTime

performing well.

4. Analysis of Scorers on Task:

Hypothesis:
$NullHypothesis$: H_0 = The mean of scores is same for both the Scorers
$AlternateHypothesis$: H_1 = The mean of scores is different for both the Scorers

Approach:Wilcox Test:

Cutting : When performed Wilcox test, p-value is greater than 0.05, which applies the means have not changed
Suturing: When performed Wilcox test, p-value is less than 0.05, which states that the means of the scorers is different.

Inference:
Scorer has an effect for Suturing and Cutting

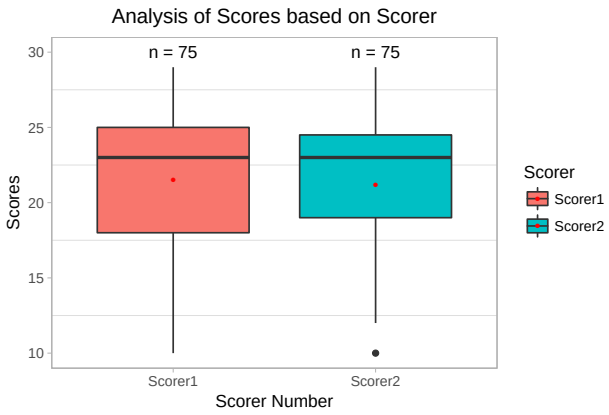

Figure 25: Cutting Scores

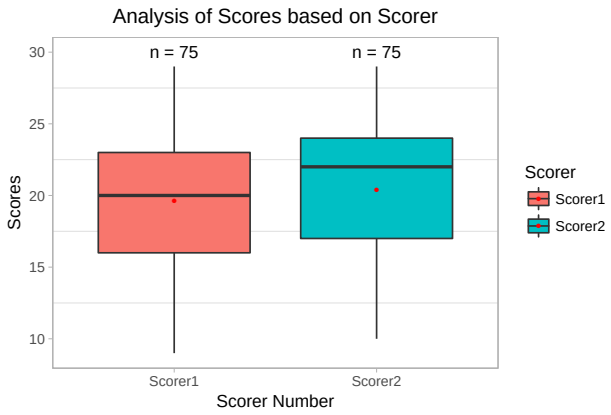

Figure 26: Suturing Scores

5. Analysis of Number of Sutures made with respect to sex and sessions:

Hypothesis:

$NullHypothesis: H_0$ = The number of sutures made is not significant on sex of the subject

$AlternateHypothesis: H_1$ = The number of sutures made is significant on sex of the subject

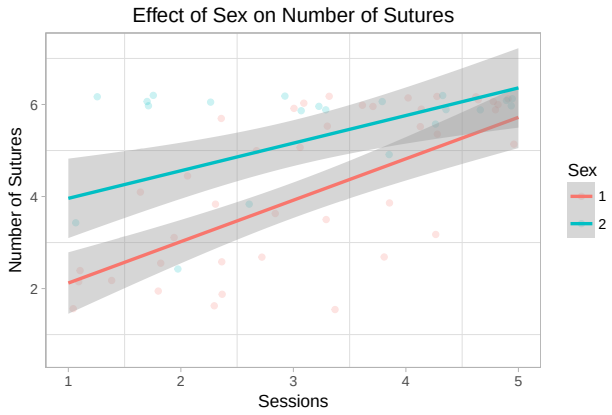

Figure 27: Interaction plot of Number of Sutures made wrt to Sex and Session

When performing the analysis for effect of Sutures on interaction of Sex and Sessions, we observe that, the p-value is 6.44e-11 which is way less than 0.05.

Also, from the interaction plot, we understand that the number of sutures made increases with the number of sessions and females make more number of sutures than males in average.

Inference:
Sex has an effect on Number of Sutures made and females made more number of Sutures in 20 minutes and the number os sutures increases with each session, i.e subject's performance gets better with each session.

6. Analysis of Performance With Respect to TAI

Hypothesis:
$NullHypothesis: H_0$ = The performance score does not depend on tai score
$AlternateHypothesis: H_1$ = With increase in tai score, the performance score decreases

Approach:T Test:

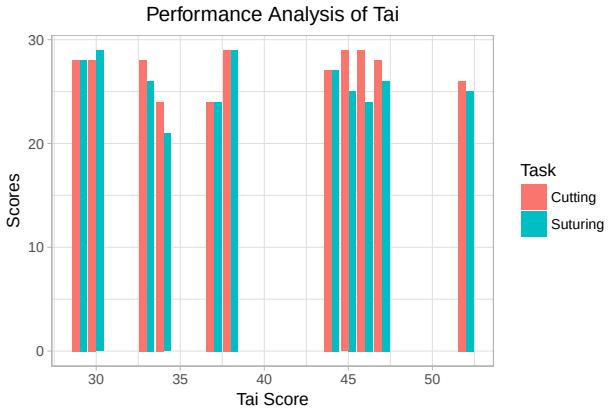

Figure 28: Analysis of Tai Vs Scores

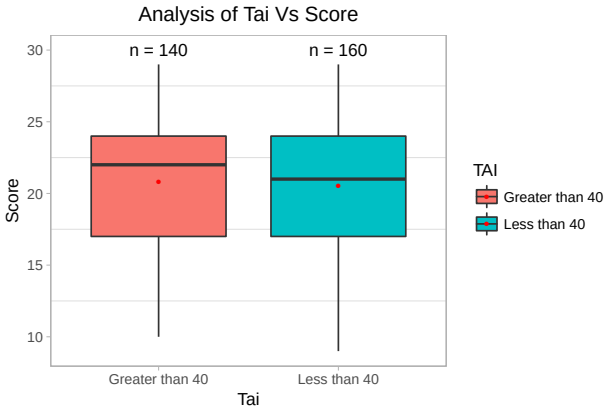

Figure 29: Analysis of Tai Vs Scores

Given, In the data, that Tai score above 40 means the subject is highly anxious. When performed T test, between all the values below or equal to 40 and above 40, we observe that the p-value is greater than 0.05, which indicates we accept the null hypothesis.
In addition, from the plots we can infer that the scores are pretty much the same, for both, above and below 40 Tai

Inference:
With this, we infer that the in general, performance does not depend on how anxious the subject is.

CONCLUSION

APPENDIX

List of Figures

1. State Psychometric Data of all Subjects

Figure 30: State Psychometric Data of all Subjects

2. Perinasal Perspiration (Stress) Signal Data of all subjects

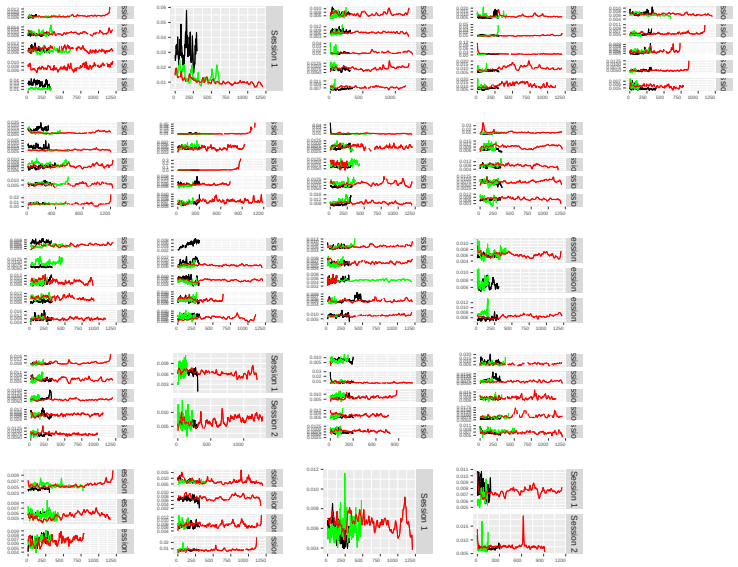

Figure 31: Perinasal Perspiration (Stress) Signal Data of all subjects

3. Suturing Time Performance of all Subjects

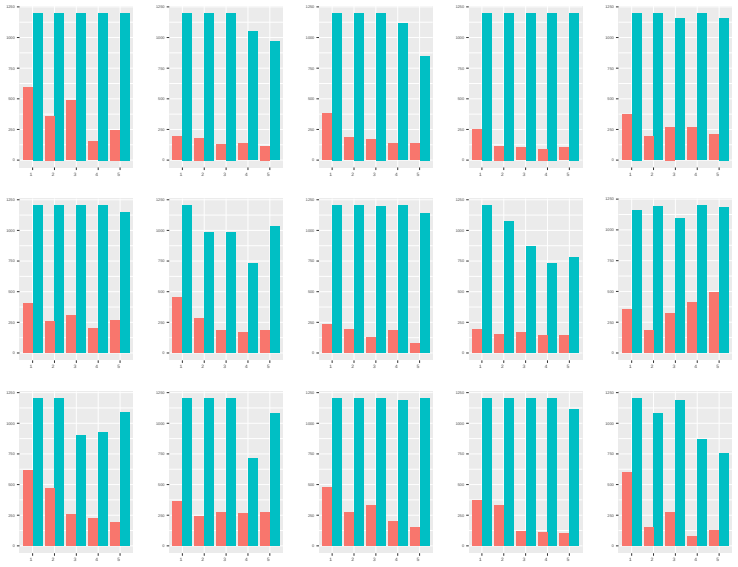

Figure 32: Suturing Time Performance of all Subjects

4.Accuracy of Scores of all subjects

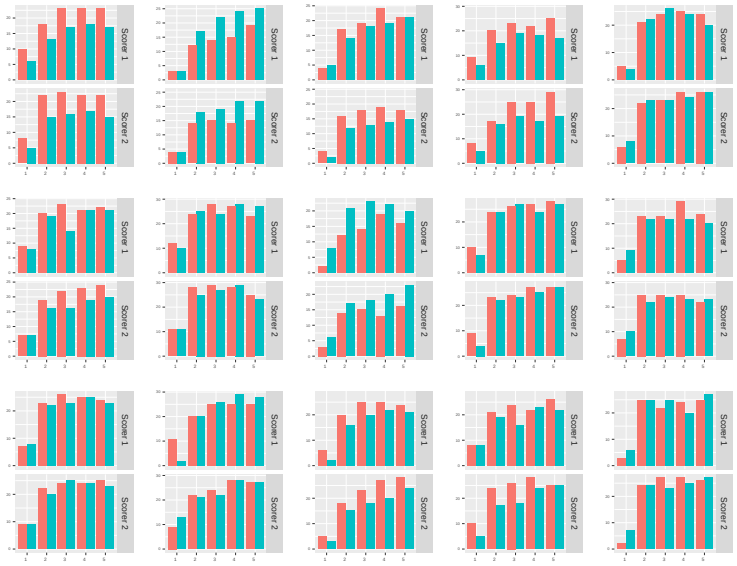

Figure 33: Accuracy of Scores of all subjects

5.Matrix Visualization of Plots of Data based on Task

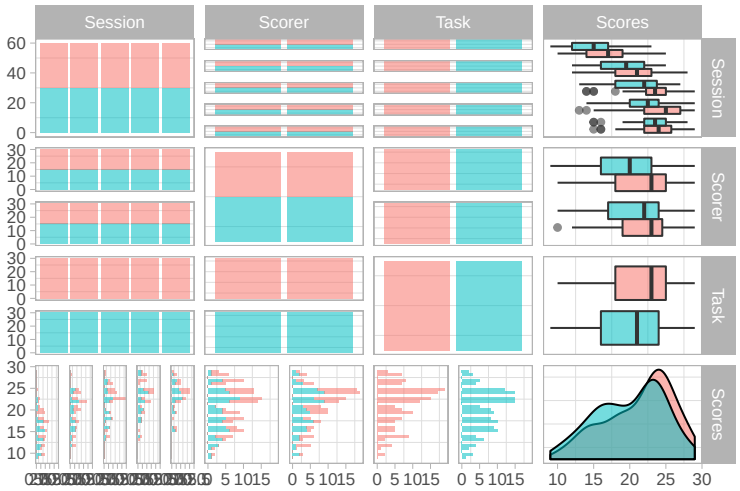

Figure 34: Accuracy of Scores of all subjects

6.Matrix Visualization of Plots of Cutting Data based on scorer

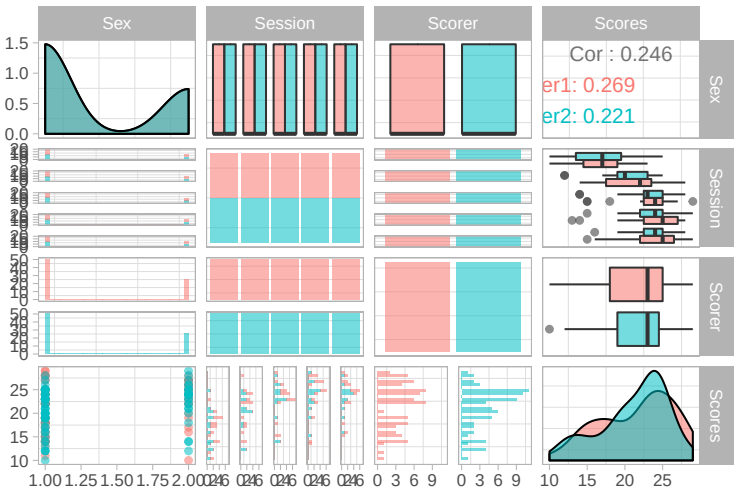

Figure 35: Accuracy of Scores of all subjects

7.Matrix Visualization of Plots of Suturing Data based on scorer

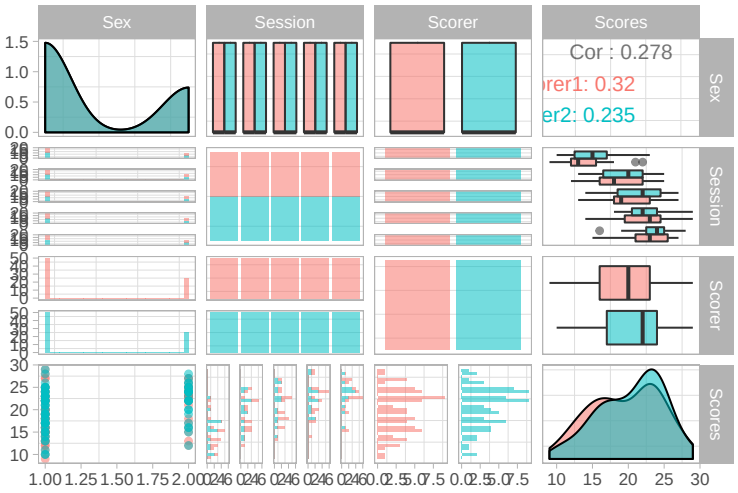

Figure 36: Accuracy of Scores of all subjects

8.Analysis of Mean Perspiration Based on Subject

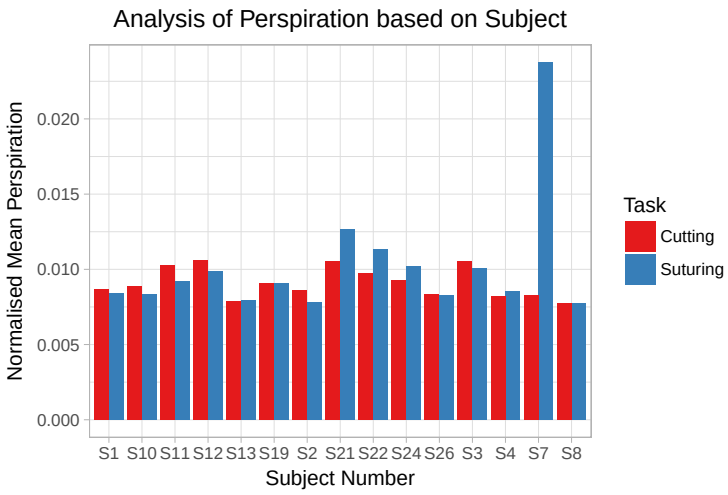

Figure 37: Accuracy of Mean Perspiration of all subjects

REFERENCES