Synchronization and Analysis of the Biomarkers Under Noise and Stress
Project Report

Industrial Project

3621655

Team Data Scientists

11.12.2019

Supervisors
Hana Vrzakova - Antti Huotarinen

1.Introduction

By definition, a biomarker is "a characteristic that is objectively measured and evaluated as an indicator of normal biological processes, pathogenic processes or pharmacological responses to a therapeutic intervention.

So, in this paper, we will propose a data summary tables, visualizations which make some comparisons by using different properties of participants, and a deep learning model which first train the model by using the experiment outcomes analysis dataset and then test the accuracy, so that we can understand how much use the collected data is. Visualizations will be provided by using both R and Python and their rich visualization tools libraries. These visualizations consist of comparisons between the participants who are working in a silent environment and noise environment.

When it comes to data types, we will be comparing those participants by using datasets coming from different sources as following; *.mp4 files of 21 participants, *.ASC files of 21 participants, *. and Experiment Outcomes Analysis File. In this project, our motivation was that environmental noise has a profound effect on one's performance and the OR can be a surprisingly noisy environment. We were having a multimodal dataset with several biometric sensors in which participants were working under silent and noisy conditions. So, our task was ;

- Learning about the study and multimodal signals
- Parsing the dataset according to video annotations and timestamp logs
- Writing scripts to conduct preliminary analysis on each modality such as signal cleaning and processing, and stats.

First, we will briefly tell you about the details of the project and project team and then share the step by step each stage of the project with the tools that we have used during that. And Finally, we will give the visualizations, observations, and results of our exploratory data analysis.

1.2. Team Information

Team Name: Team Data Scientists

Name and Surname	Student ID	Role
Fatima Rabia Yapicioglu	306627	Chairperson, Report Editor, Content Creator, Data Scientists
Mariia Sorokina	306548	Content Distributor & Data Scientist
Rhythm Bhatia	308847	Tool Searcher & Data Scientist

1.3. Project Details

Project Name: Synchronization and Analysis of the Biomarkers Under Noise and Stress.

Data Collected: 21 Participant's .mp4 video file (annotated frame by frame), *.ASC Files (Physiological Signals), Experiment Outcomes Analysis.xlsx File.

Tools that are used: Boris, Tracker, Jupyter Notebook, Kaggle, Python/R, Matplotlib, Seaborn, Plotly.

Purpose: Analyzing the data of biomarkers who work under stress and noise by making a summary boxplot graph in Python/R to show how long each task lasted for all participants. And for each participant, computing the mean and standard deviation for each physiology signal. Finally, visualizing the data and results.

Supervisors: Hana Vrzakova - Antti Huotarinen

Teacher: Markku Hauta-Kasari

2. Methods

2.1. Data Collection Methods

In the first part of our project, we collected the data from *.mp4 files. We had three tasks and three sessions for each participant. Each task was having a pre-exposure, exposure and post-exposure sessions. Task names were as following: Mesh Alignment, Knotting, and Go-Around. We recorded the starting and ending frame numbers of each task.

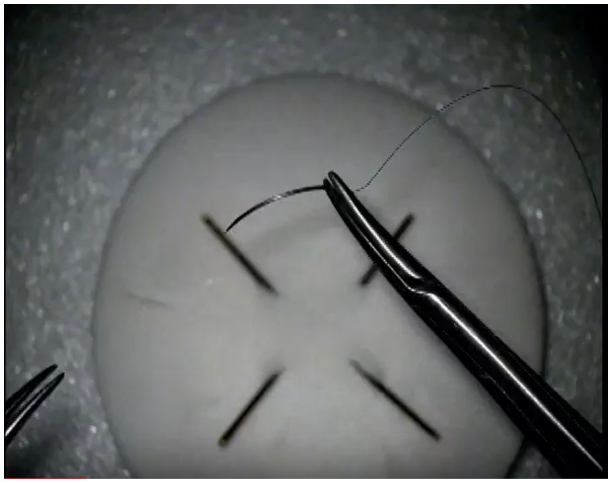


Figure 2.1. Go-Around Start.

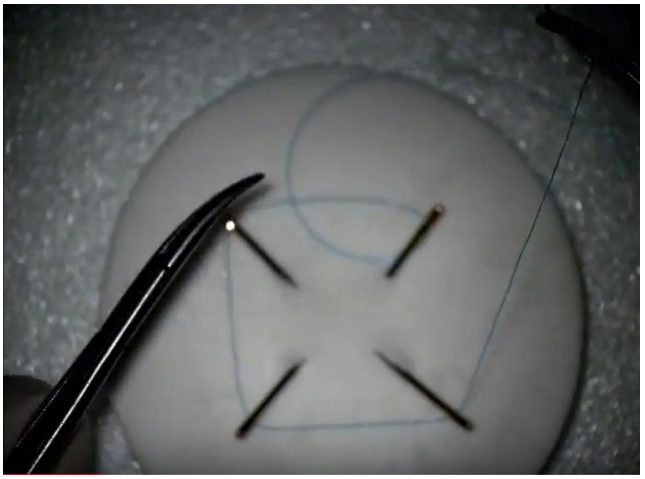


Figure 2.2. Go-Around End.

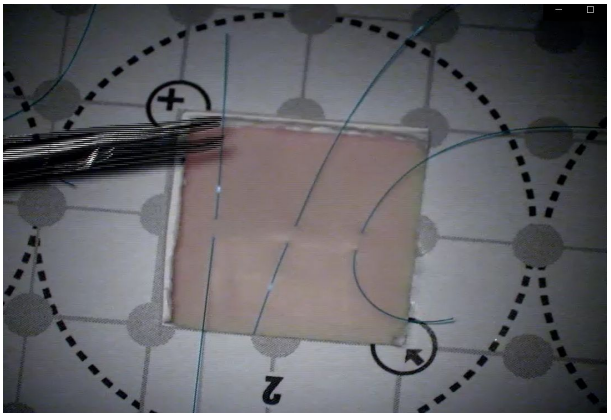


Figure 2.3. Knotting Start.

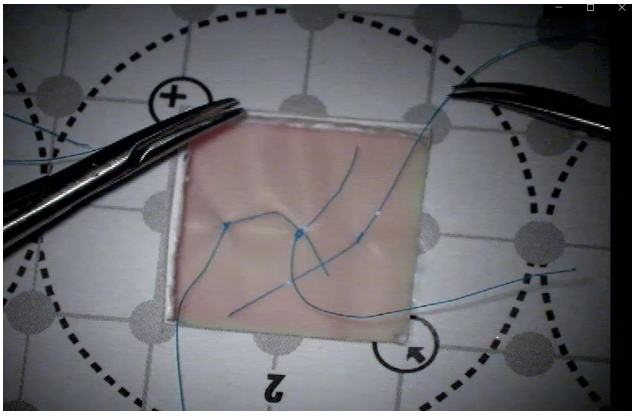


Figure 2.4. Knotting End.

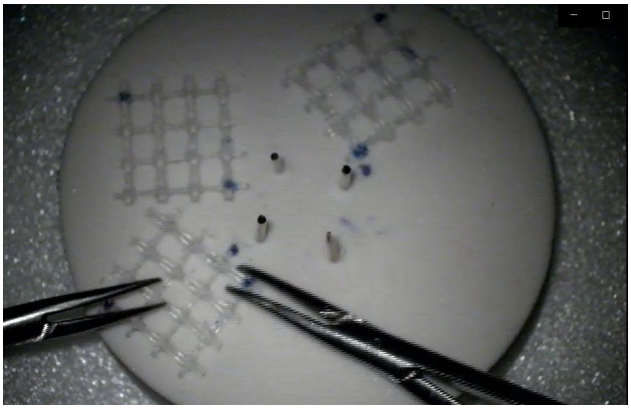


Figure 2.5. Mesh Alignment Start.

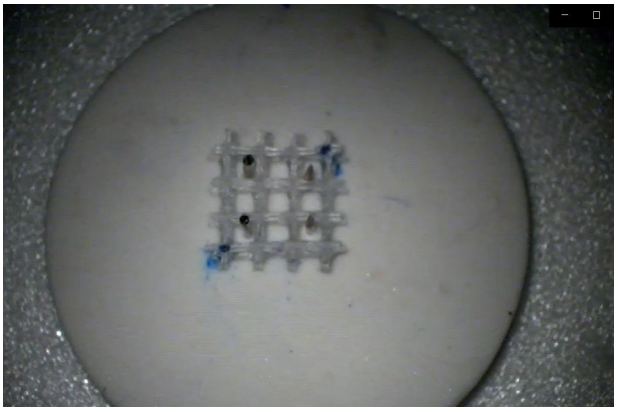


Figure 2.6. Mesh Alignment End.

By using the above information we filled the excel table which is provided by our supervisors as it can also be seen in the following **Figure 2.7.**

ParticipantID	Phase	Task	Task name	Repetition	Start	End
P1	Pre-exposure	Task 1	Mesh Alignment	Trial 1	26265	26990
P1	Pre-exposure	Task 1	Mesh Alignment	Trial 2	29245	29600
P1	Pre-exposure	Task 1	Mesh Alignment	Trial 3	30795	31565
P1	Pre-exposure	Task 2	Knotting	Trial 1	20538	22322
P1	Pre-exposure	Task 2	Knotting	Trial 2	-	-
P1	Pre-exposure	Task 2	Knotting	Trial 3	-	-
P1	Pre-exposure	Task 3	Go-around	Trial 1	9427	10839
P1	Pre-exposure	Task 3	Go-around	Trial 2	13615	14596
P1	Pre-exposure	Task 3	Go-around	Trial 3	16616	17436

Figure 2.7. Frame Numbers Table - Excel File.

Eye-tracker video annotating software tool uses 15 fps(frame per second) which is equal to 15 Hz.So, 1/15 is nearly equal to 0.06 second. And then we will use this data to show how long each task is lasting in the experiment outcomes analysis.

In the second part of the data collection, we had *.ASC files which consist of the physiological signals.When we open this *.ASC file and cleaned the data we can see the following table in **Figure 2.8.**

	Lihas1	Lihas2	Lihas3	Lihas4	EKG	EOG	Lämpötila	Kiihtyvyy x	Kiihtyvyys y	Kiihtyvyys z	GSR
	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
1	-20	1	-7	-12	58	5379	-1259	8041	8043	8044	-2660
2	-10	4	-2	-11	62	4741	-1258	8045	8043	8045	-2650
3	-23	8	-3	-16	58	-4337	-1266	8041	8043	8041	-2636
4	-20	10	13	-17	64	-6147	-1264	8041	8043	8045	-2637
5	-9	10	20	-15	69	-6294	-1263	8041	8043	8045	-2638
6	-5	6	12	-10	74	-6247	-1265	8040	8042	8043	-2639

Figure 2.8. *.ASC File.

And here the column explanations can be made as follows,

[SOURCE NAMES]

Lihas1 << muscle group 1 on the left hand
Lihas2 << muscle group 2 on the left hand
Lihas3 << muscle group 1 on the right-hand
Lihas4 << muscle group 2 on the right-hand
EKG << heart rate
EOG << electrooculography - we didn't use that
Kiihtyvyy x << accelerometer at the hand (x)
Kiihtyvyys y << accelerometer at the hand (y)
Kiihtyvyys z << accelerometer at the hand (z)
GSR << galvanic skin response

And in the third part of our project, we provided the Experiment Outcomes Analysis file which has each participant's ID, Gender, Mental Demands, Physical Demands, Temporal Demands, Task Complexity, Distractions and Condition columns as it can also be seen in the following table.

	Date	Gender	ID	Condition	task_1_PRE	task_2_PRE	task_3_PRE	task_1_EX	task_2_EX	task_3_EX	...	Physical_demands	Temporal_demands	Ta
0	23.11.2017	F	P1	Noise	2	1	3	3	2	1	...	13	8	
1	23.11.2017	M	P2	Silent	3	1	2	1	2	3	...	6	2	
2	23.11.2017	F	P3	Noise	1	3	2	1	3	2	...	9	6	
3	24.11.2017	F	P4	Silent	2	1	3	3	1	2	...	8	6	
4	24.11.2017	M	P5	Noise	3	2	1	2	3	1	...	18	1	

5 rows × 24 columns

Figure 2.9. Experiment Outcomes Analysis Dataset.

So, these are the data files, sources and data collection methods that we have used in this project to investigate biomarkers' activity.

2.2. Data Summary and Visualization Methods

We provided each and every dataset's first 2 or 5 lines to explain the content to the user first. And then by using Python and it's data description methods we calculated the count of participants both working in a silent and noisy environment, mean, standard deviation, min, max, etc. We also built a data summary table by using R and manually calculated mean, standard deviation, min, max, etc. And to see the correlations between attributes we have used heatmaps which provide a facility to recognize correlation levels by color. We provided 3D visualizations to see each participant in a 3D dimensional graph. To discriminate or see the difference between noise and silent environments we implemented the t-test, p-value and created the tables. Finally, we built an artificial intelligence model to test the quality of the properties. We cleaned the data by pre-processing and scaled, then trained and then test the accuracy. But this is extra work, which is not included in the procedures which are provided by our supervisor. And for the visualizations, we both used Python and R's data visualization tools like Matplotlib, Seaborn, Ggplot2, etc. to create 2D visualizations.

3. Experiments and Outcomes

3.1.Correlations

To see the correlations between data attributes we used the heatmap method of Python. We implemented this both for participants who are working in a noisy environment and silent environment, to make comparison between them.

```
f,ax = plt.subplots(figsize=(15, 15))
sns.heatmap(noise_participants.corr(), annot=True,
linewidths=0.5,linecolor="red", fmt= '.1f',ax=ax)
plt.show()
```

And as an outcome, we have got the following picture both for noise and silent environment participants. We will discuss our findings and observations in the results section.

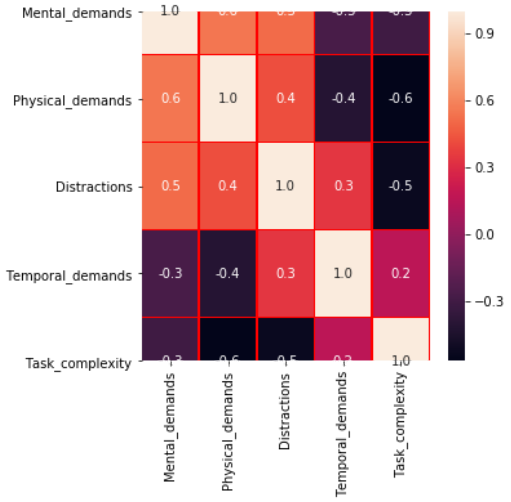


Figure 3.1. Heatmap Table.

After seeing the correlations between the data attributes we needed to visualize the Mental demands, Physical demands, Temporal demands, etc. to immerse data better. So, by using some different visualization tools we got the following pictures.

```
k <- ggplot(df, aes(factor(Condition), fill = factor(Mental_demands)))
k + geom_bar()
```

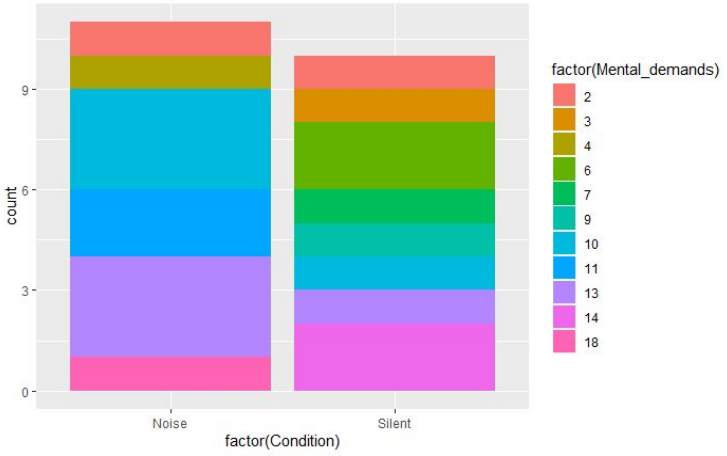


Figure 3.2. Mental demands of Noise and Silent Conditions.

Or if we want to see all of the demands together, we can use multiple bar plots together as follows,

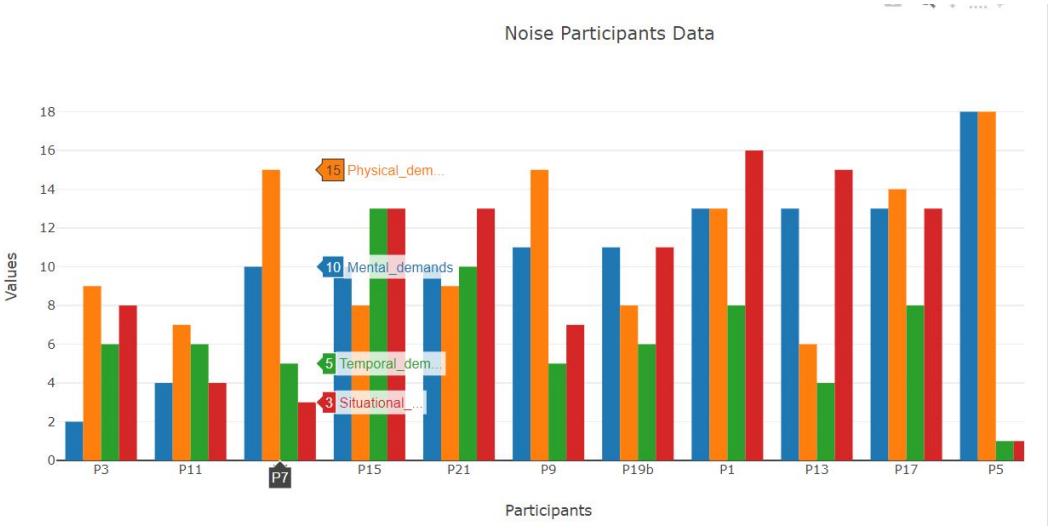


Figure 3.3. Mental demands of Noise and Silent Conditions.

By using R we can visualize each demand by using boxplots so that we can see the mean value and outliers at the same time.

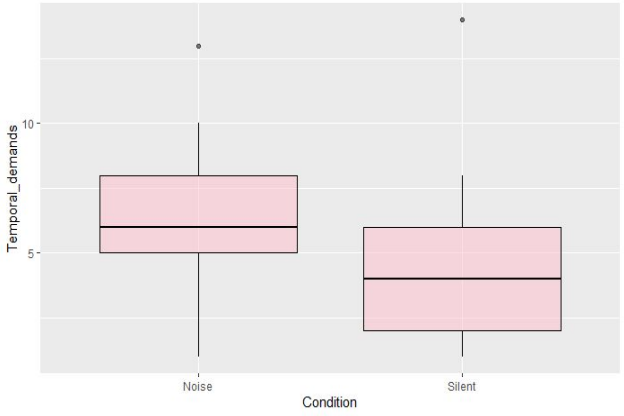
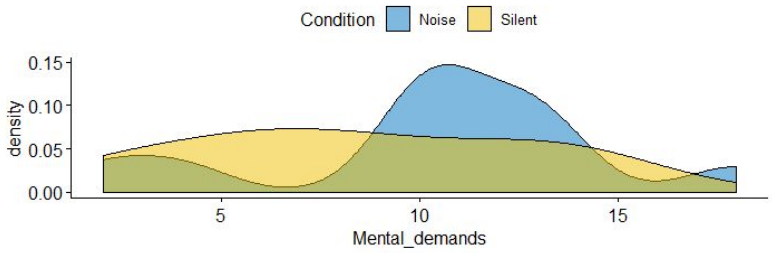


Figure 3.4. Temporal Demands in a Boxplot.

We also visualized each demand in a density graph by calculating the mean and standard deviation as follows,



Condition	mean	sd
Noise	10.45455	4.367233
Silent	8.40000	4.351245

Figure 3.5. Mental Demands in a Density Graph.

4.Results

4.1.Summary, Participants in Noise and Silent Environment

Here count means there are 11 participants working in a noisy environment, mean of mental demands is nearly 10.45, the standard deviation is 4.36, the minimum is 2.0 and the maximum is 18.0. Physical demand's mean is 11.0, the standard deviation is 4.0, the minimum is 6.0 and the maximum is 18.0. And if we look at the task complexity the mean is 9.2, but when we look at the std then we can understand that the task complexity changes in a wide range. The standard deviation rate is at least 3.1 which means participants nearly need it at the same amount. When the task complexity changes mental demands and the physical demands also change in the same amount if we observe the standard deviations.

```
1  s1=noise_participants.describe().T.tail(7)
2  s1
```

	count	mean	std	min	25%	50%	75%	max
Mental_demands	11.0	10.454545	4.367233	2.0	10.0	11.0	13.0	18.0
Physical_demands	11.0	11.090909	4.011348	6.0	8.0	9.0	14.5	18.0
Temporal_demands	11.0	6.545455	3.173756	1.0	5.0	6.0	8.0	13.0
Task_complexity	11.0	9.272727	4.244783	1.0	7.0	9.0	12.5	15.0
Situational_stress	11.0	9.454545	5.145165	1.0	5.5	11.0	13.0	16.0
Distractions	11.0	8.454545	4.719399	1.0	4.5	9.0	11.5	16.0
Surg_otal	11.0	55.272727	12.337673	30.0	49.0	57.0	65.5	71.0

Figure 4.1. Summary table of participants in a Noise Environment.

And when we look at the silent environment workers Mental demand's mean is 8.4, Physical demand's mean is 5.9, Task complexity's mean is 6.7, Situational stress's mean is 5.6 and for the distractions, we got 3.3 as a mean. But when we investigate the standard deviations for Physical demands and distractions got the minimum values, which means that when they focus on their work in a silent environment they need nearly the same physical demands.

```
s2=silent_participants.describe().T.tail(7)
s2
```

	count	mean	std	min	25%	50%	75%	max
Mental_demands	10.0	8.4	4.351245	2.0	6.00	8.0	12.25	14.0
Physical_demands	10.0	5.9	2.766867	3.0	3.25	6.0	7.50	11.0
Temporal_demands	10.0	4.8	4.022161	1.0	2.00	4.0	6.00	14.0
Task_complexity	10.0	6.7	5.250397	1.0	3.00	4.0	12.25	14.0
Situational_stress	10.0	5.6	4.376706	1.0	2.00	4.5	8.75	13.0
Distractions	10.0	3.3	2.162817	1.0	1.25	3.0	5.00	7.0
Surg_otal	10.0	34.7	14.126807	18.0	25.25	32.0	39.00	67.0

Figure 4.2. Summary table of participants in a Silent Environment.

So, when we compare the Mental demands of noisy environment workers and silent environment workers, noisy workers need 10.4 and silent workers need 8.4 at their mean values. Noises may have some bad effects on the mental demands of each participant as it can also be grouped by as follows,

```
df.groupby("Condition")['Mental_demands'].describe()
```

	count	mean	std	min	25%	50%	75%	max
Condition								
Noise	11.0	10.454545	4.367233	2.0	10.0	11.0	13.00	18.0
Silent	10.0	8.400000	4.351245	2.0	6.0	8.0	12.25	14.0

Figure 4.2. Group by Condition of Mental demands

Also for the Physical demands, Noisy workers need 11.0 and Silent workers need 5.9, we can easily see that there is a gap between these two values. Noises also have big bad effects on the physical demands of participants. There is another big difference can also be seen in the distractions 8.4 and 2.1 again noises create distractions on the participants. We can see this difference as following clearly,

```
1 df.groupby("Condition")['Physical_demands'].describe()
```

Condition	count	mean	std	min	25%	50%	75%	max
Noise	11.0	11.090909	4.011348	6.0	8.00	9.0	14.5	18.0
Silent	10.0	5.900000	2.766867	3.0	3.25	6.0	7.5	11.0

Figure 4.3. Group by Condition of physical demands

Also for the attributes we can see the differences easily, we also calculated the temporal demands and distractions.

```
1 df.groupby("Condition")['Temporal_demands'].describe()
```

Condition	count	mean	std	min	25%	50%	75%	max
Noise	11.0	6.545455	3.173756	1.0	5.0	6.0	8.0	13.0
Silent	10.0	4.800000	4.022161	1.0	2.0	4.0	6.0	14.0

```
1 df.groupby("Condition")['Task_complexity'].describe()
```

Condition	count	mean	std	min	25%	50%	75%	max
Noise	11.0	9.272727	4.244783	1.0	7.0	9.0	12.50	15.0
Silent	10.0	6.700000	5.250397	1.0	3.0	4.0	12.25	14.0

Figure 4.4. Group by Condition of temporal demands and task complexity.

We also plotted other attributes by using Matplotlib so that you can observe them all.

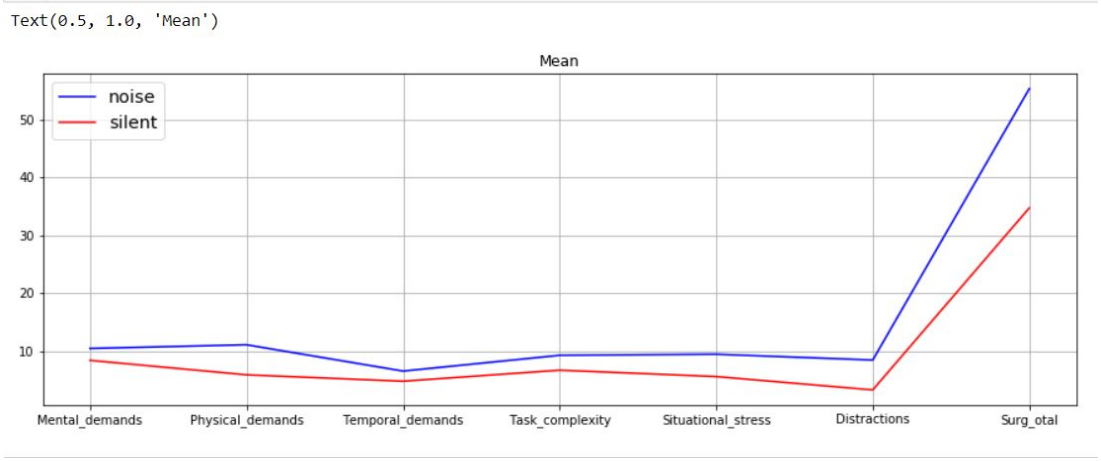


Figure 4.3. Comparison of Mean Values of Noise and Silent Environment Participants.

4.2.Two sample t-test

The two-sample t-test is one of the most commonly used hypothesis tests in Six Sigma work. It is applied to compare whether the average difference between the two groups is really significant or if it is due instead to random chance. And we have calculated the t-test values as follows and we got the results in **Figure 4.5.**

Mental Demands	Test Statistic	p-value	
Sample Data	1.0785719104519582	0.2942817213459388	EDIT CHART
Physical Demands	**Test Statistic**	**p-value**	
Sample Data	3.4160429024727317	0.0028973685939021046	EDIT CHART
Temporal Demands	**Test Statistic**	**p-value**	
Sample Data	1.1094705787911137	0.2810728450631287	EDIT CHART
Distractions	**Test Statistic**	**p-value**	
Sample Data	3.1598940082139584	0.0051571612986448506	EDIT CHART

Figure 4.5. Two sample t-test results.

So the biggest difference between the mean values can be seen in the Physical demands because the t-test value takes its maximum value in this attribute. And the minimum t-test value here is in Mental demands which means the averages close to each other when compared with the others.

4.3. Visualizations of Physiological Signals

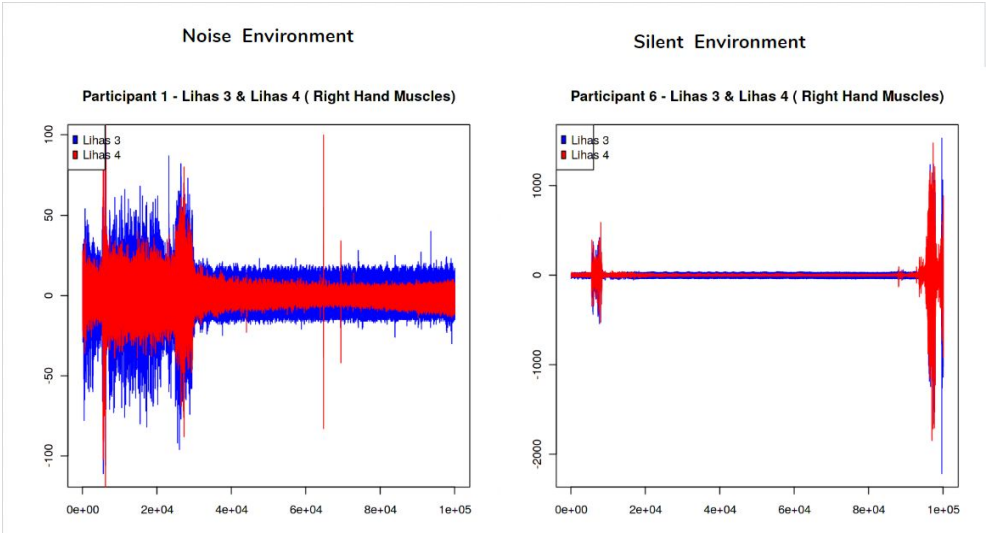


Figure 4.6. Comparison of Right-Hand Muscles in a Noise and Silent Environment.

The participants who are working in a noisy environment has more muscle activity when compared to the silent environment participants.The same difference also can be observed when we look at the left-hand muscle groups.

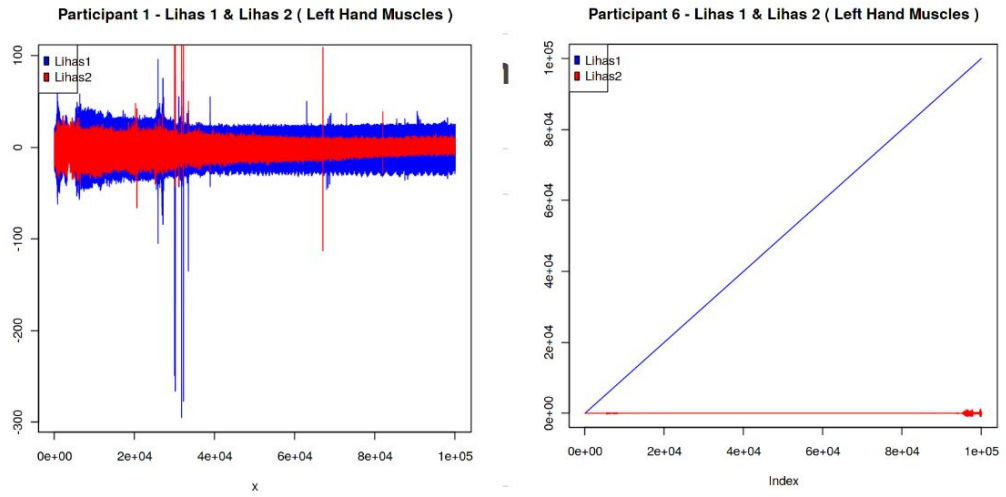


Figure 4.7. Comparison of Left-Hand Muscles in a Noise and Silent Environment.

We also have the EKG data of the participants, we visualized this data also and got the following results. So, in the output, we can also observe the heart-beat rate of the noisy environment participant's variety is much more than the silent environment participants.

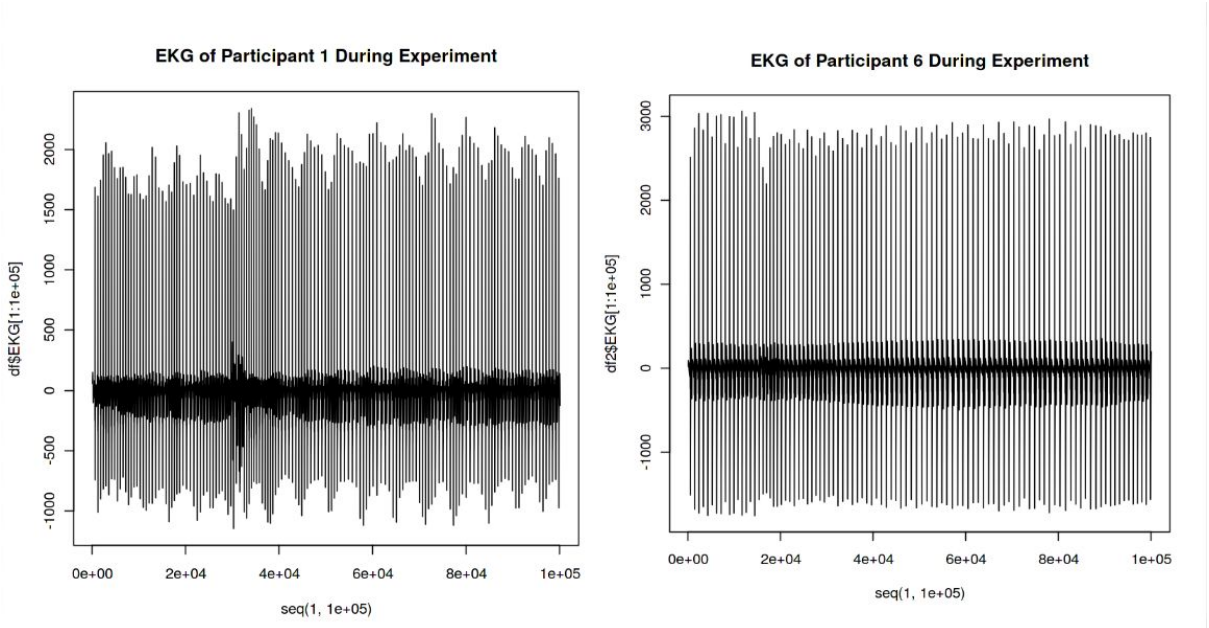


Figure 4.8. Comparison of EKG rates of Participants working a Noise and Silent Environment.

4.4. Data Summary of Physiological Signals

Participant 1 - Noise Environment

Lihas1	Lihas2	Lihas3	Lihas4
Min. :-3075.000	Min. :-3413.000	Min. :-3371.00	Min. :-6169.000
1st Qu.: -45.000	1st Qu.: -21.000	1st Qu.: -25.00	1st Qu.: -24.000
Median : 0.000	Median : 0.000	Median : 1.00	Median : 1.000
Mean : 0.217	Mean : -0.577	Mean : -0.61	Mean : -0.825
3rd Qu.: 41.000	3rd Qu.: 19.000	3rd Qu.: 26.00	3rd Qu.: 26.000
Max. : 3901.000	Max. : 3557.000	Max. : 5242.00	Max. : 3589.000

EKG	EOG	Lämpötila	Kiihtyvyys x	Kiihtyvyys y
Min. :-5952	Min. :-6561	Min. :-2144	Min. :8029	Min. :8031
1st Qu.: -112	1st Qu.:-6263	1st Qu.:-1474	1st Qu.:8035	1st Qu.:8037
Median : -17	Median :-5342	Median :-1440	Median :8036	Median :8038
Mean : -19	Mean :-1021	Mean :-1423	Mean :8036	Mean :8038
3rd Qu.: 36	3rd Qu.: 5704	3rd Qu.:-1381	3rd Qu.:8037	3rd Qu.:8039
Max. : 2953	Max. : 6158	Max. : -822	Max. :8046	Max. :8047

Kiihtyvyys z	GSR
Min. :8032	Min. :-6906
1st Qu.:8037	1st Qu.: -446
Median :8039	Median : 1496
Mean :8039	Mean : 1687
3rd Qu.:8040	3rd Qu.: 4571
Max. :8048	Max. : 5746

Participant 6 - Silent Environment

V1	V2	V3	V4
Mode:logical	Min. :-4229.000	Min. :-2688.0000	Min. :-4071.000
NA's:3679514	1st Qu.: -16.000	1st Qu.: -18.0000	1st Qu.: -19.000
	Median : 2.000	Median : 0.0000	Median : 1.000
	Mean : 1.409	Mean : 0.6283	Mean : 0.298
	3rd Qu.: 22.000	3rd Qu.: 22.0000	3rd Qu.: 21.000
	Max. : 3373.000	Max. : 2470.0000	Max. : 2732.000

V5	V6	V7	V8
Min. :-3671.000	Min. :-2033.00	Min. :-6460.0	Min. :-1223.0
1st Qu.: -27.000	1st Qu.: -70.00	1st Qu.:-6240.0	1st Qu.:-1079.0
Median : 0.000	Median : -3.00	Median :-4328.0	Median : -995.0
Mean : 0.202	Mean : -18.27	Mean : -674.1	Mean : -996.6
3rd Qu.: 26.000	3rd Qu.: 49.00	3rd Qu.: 5616.0	3rd Qu.: -916.0
Max. : 2255.000	Max. : 3449.00	Max. : 6118.0	Max. : -750.0

V9	V10	V11	V12
Min. : -1	Min. : -1	Min. :8028	Min. :-4321
1st Qu.:8035	1st Qu.:8037	1st Qu.:8038	1st Qu.:-2188
Median :8037	Median :8039	Median :8039	Median :-1909
Mean :8037	Mean :8039	Mean :8040	Mean :-1721
3rd Qu.:8039	3rd Qu.:8040	3rd Qu.:8041	3rd Qu.:-1256
Max. :8052	Max. :8053	Max. :8054	Max. : 605

4.5. General Visualizations

This project would have been enriched by adding some larger visualizations which can make wide range comparisons as follows.

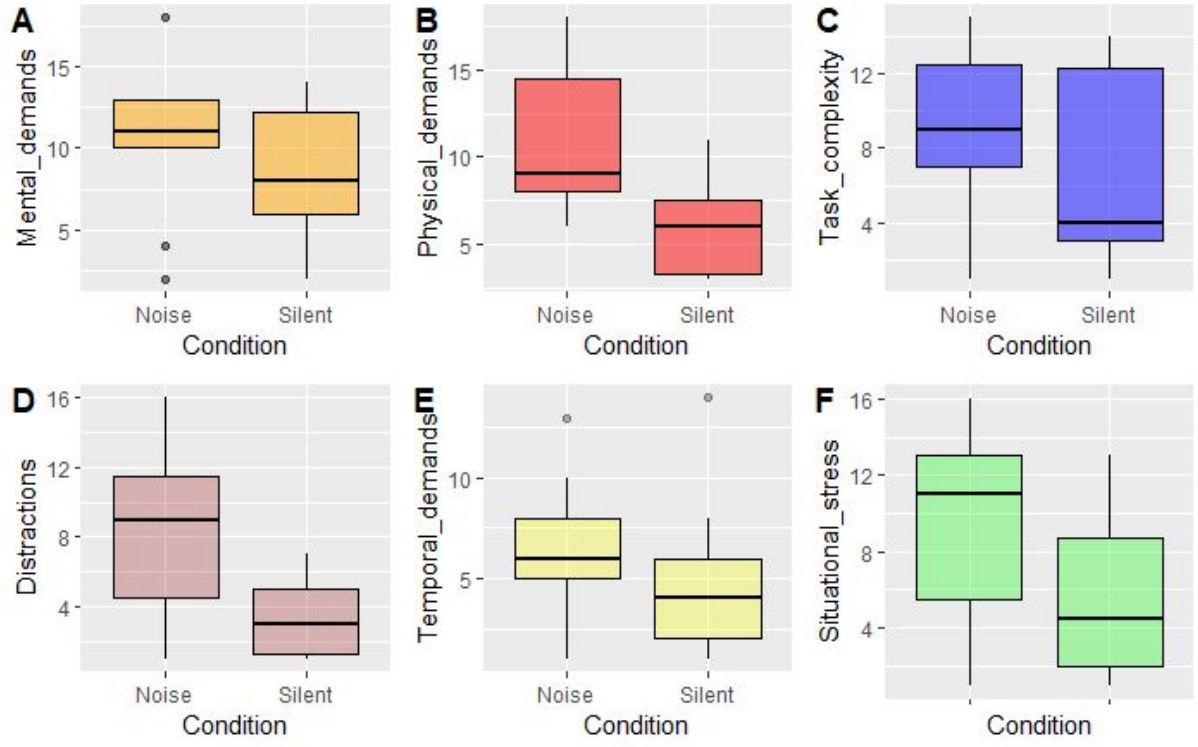


Figure 4.9. General Box plot grouped by condition

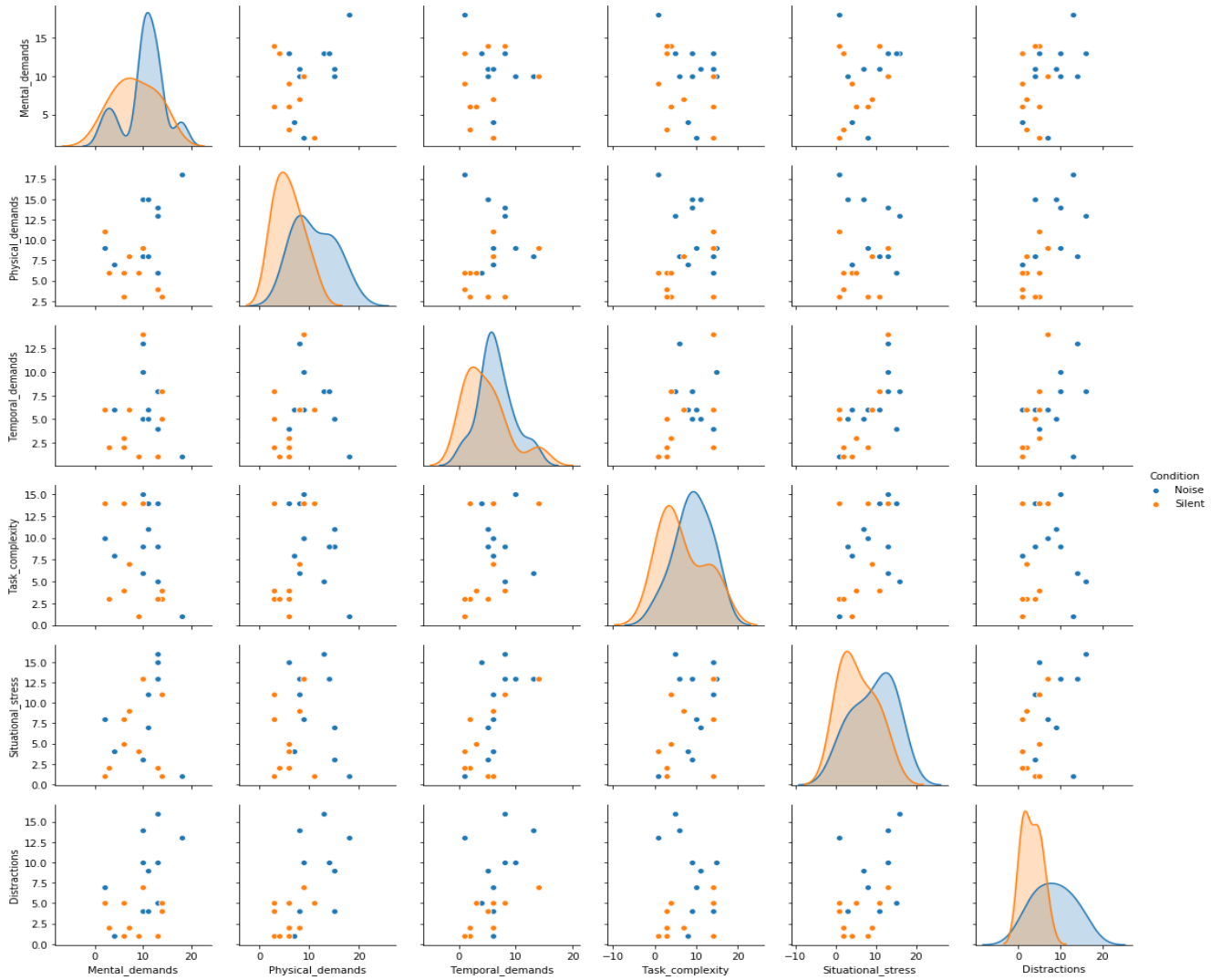


Figure 4.9. General Pair plot grouped by condition

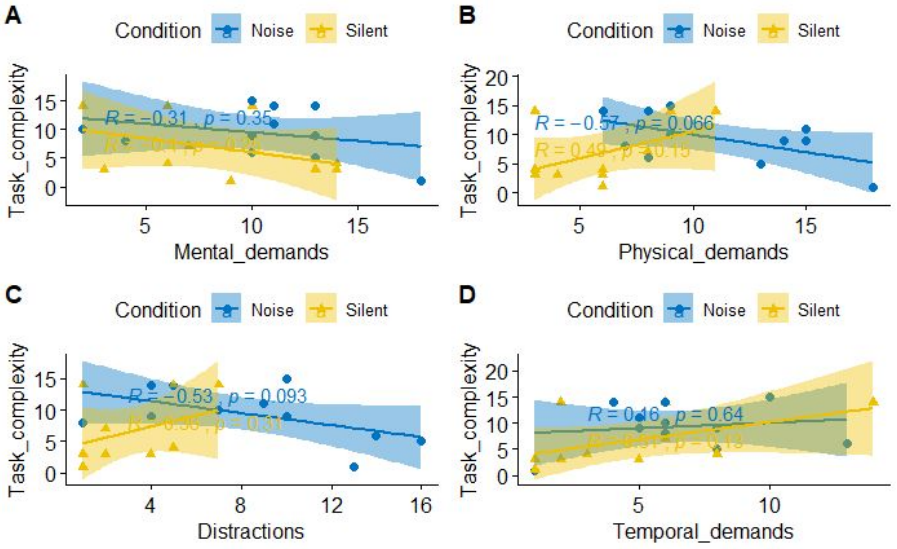


Figure 4.10. General R and p-value visualization grouped by condition

5. Conclusions and Discussion

In a nutshell, we made an exploratory data analysis of both participants working in a silent environment and noisy environment and made a detailed comparison between them. And we proved that noise has some bad effects on the participant's Mental demands, Physical demands, Temporal demands, and Task Complexity. And there are some big differences between the mean values of them as it can be understood from the t-test results.

Also, during the experiment, our supervisor Hana found a paper with the experiment scheme (JPG).
The experiment scheme shows how many repetitions and how many subtasks were in each phase.

The experiment outcomes tell which participants were doing which condition; what was the order of the tasks; and what was their self-reported outcomes. Supervisors asked them how difficult was the task (using https://en.wikipedia.org/wiki/NASA-TLX) and how good they felt in knotting (using https://www.ncbi.nlm.nih.gov/pubmed/21200214).

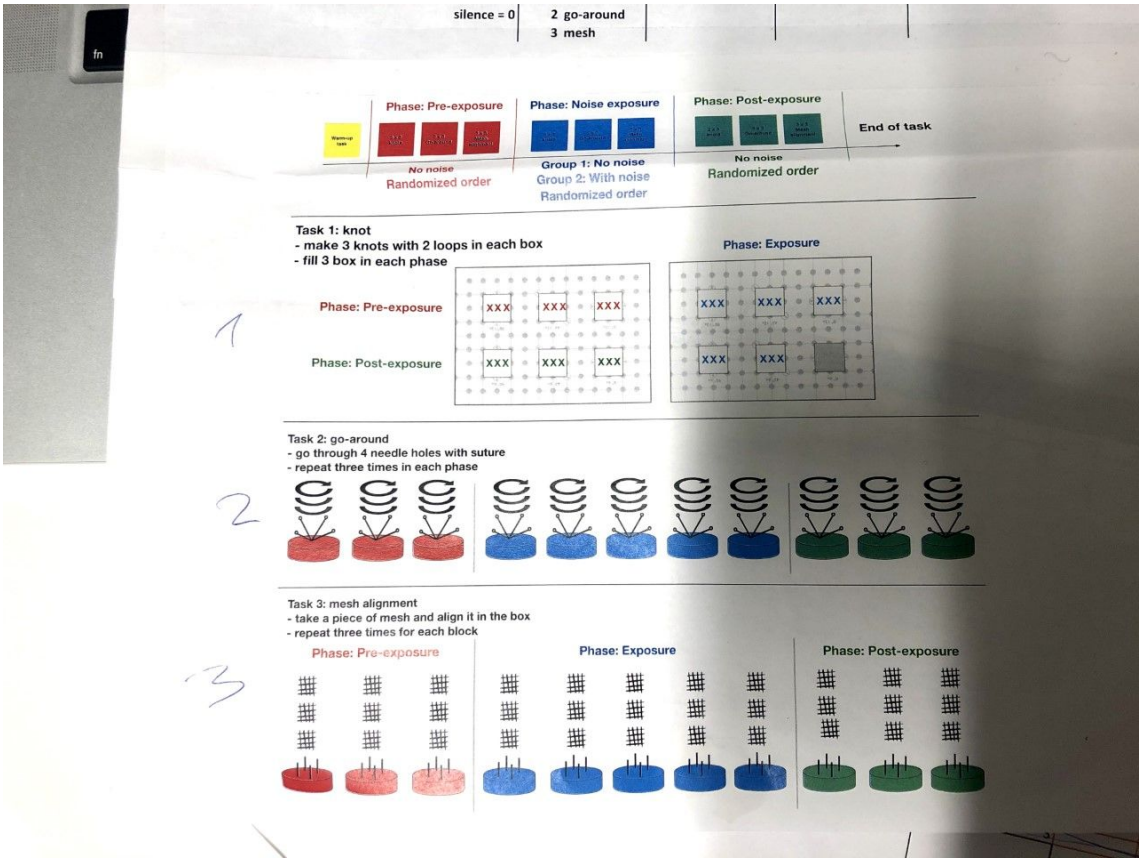


Figure 5.1. Experiment Scheme.

AI Model

Our Aı model by using the experiment outcomes results in analysis.

```
eval_model=classifier.evaluate(X_train, y_train)
eval_model
#loss and accuracy of our model by using these properties
```

```
14/14 [==============================] - 0s 8ms/step
```

```
[0.32872629165649414, 0.9285714030265808]
```

```
y_pred=classifier.predict(X_test)
y_pred =(y_pred>0.5)
```

```
from sklearn.metrics import confusion_matrix
cm = confusion_matrix(y_test, y_pred)
print(cm)
```

```
[[2 0]
 [1 4]]
```

6.References

Chrouser,K.L.,Xu,J.,Hallbeck,M.S.,Weinger,M.B.,Partin,M.R.(2018) The influence of stress responses on surgical performance and outcomes: literature review and the development of the surgical stress effects (SSE) framework.

https://doi.org/10.1016/j.amjsurg.2018.02.017.

Jones KI, Amawi F, Bhalla A, Peacock O, Williams JP, Lundt JN (2014) Assessing surgeon stress when operating using heart rate variability and the states trait anxiety inventory: will surgery be the death of us?

https://doi.org/10.1111/codi.12844

Ljungberg,J.K., Neely G.(2007). Stress, subjective experience and cognitive performance during exposure to noise and vibration;

https://doi.org/10.1016/j.jenvp.2006.12.003

Way TJ, Long A, Weihing J et al (2013) Effect of noise on auditory processing in the operating room.

https://doi.org/10.1016/j.jamcollsurg.2012.12.048

Moorthy K, Munz Y, Undre S, Darzi A (2004) Objective evaluation of the effect of noise on the performance of a complex laparoscopic task.

https://doi.org/10.1016/j.surg.2003.12.011

S. Arora, N. Sevdalis, D. Nestel, M. Woloshynowych, A. Darzi, R. Kneebone (2010) The impact of stress on surgical performance: a systematic review of the literature

https://doi.org/10.1016/j.surg.2009.10.007

Berguer R, Smith W. (2006) An ergonomic comparison of robotic and laparoscopic technique: the influence of surgeon experience and task complexity.

https://doi.org/10.1016/j.jss.2005.10.003

Gerard P van Galen, Martijn van Huygevoort (2000) Error, stress and the role of neuromotor noise in space oriented behaviour

https://doi.org/10.1016/S0301-0511(99)00037-X

M.Spreng (2000) Possible health effects of noise induced cortisol increase

http://www.noiseandhealth.org/article.asp?issn=1463-1741;year=2000;volume=2;issue=7;spage=59;epage=63;aulast=Spreng

E A Anderson, B G Wallin, and A L Mark (1987) Dissociation of sympathetic nerve activity in arm and leg muscle during mental stress

https://www.ahajournals.org/doi/10.1161/01.HYP.9.6_Pt_2.III114

J. Gomes, O. Lloyd, N. Norman(2002) The health of the workers in a rapidly developing country: effects of occupational exposure to noise and heat, Occupational Medicine, Volume 52, Issue 3, Pages 121–128

https://doi.org/10.1093/occmed/52.3.121