Validity of the Signal set

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1 Introduction

In this phase of the project, we check for validity of the data by conducting couple of tests on segmented data in the form of phases and then conclude if there are significant differences being observed in the data by making a pairwise comparisons between various phases MD vs ND, CD vs ND, ED vs ND. We keep ND ie Normal Drive as a constant phase for making pairwise comparisons.The reason behind this is obvious that ND is a Normal Drive session which is perceived as drivers behaviour and his reactions when no sort of stress is applied.So, this forms a baseline for all the pairwise comparisons being made on all the 4-7 sessions with respect to ND.
NOTE:We are conducting a **crossover experimental design** here, as we can see that the same set of subjects are being tested on various sessions like Emotional Drive, Normal Drive, Cognitive Drive and Motoric Drive. So, as this design is a crossover one, we are required to do a paired-t test. Had it been a parallel group design where 2 sets of patients have different testing conditions,we would have proceeded with a one-way ANOVA.

2 Data Extraction and it's Interpretation

We consider 4-7 sessions ie MD,CD and ED and in that, we take into consideration .BR(Breathing Rate),.HR(heart Rate),.pp(Noise Reduced Perinasal),.peda(Palm EDA) signals for analysis. As a first step towards data extraction, we consider the .stm time slice files that has 2 time ranges. The first and second time range value ranges gives us the stressed phases of the subject's HR/BR/pp/PEDA values. Essentially we consdier 0-T1 (Phase 1/Non Stressed), T1-T2(Phase 2/Stressed), T2-T3(Phase 3/Non stressed), T3-T4(Phase 4/Stressed),T4-End(Phase 5/Non stressed). After extraction of these respective time slice values from CD/MD/ED sessions of HR,BR,Peda,PP signal sets,we proceed on to extraction of the same from ND session's HR,BR,Peda,PP files.This completes the initial data extraction phase. After the extraction of these time slices ie phases of all the sessions and it's signal sets, we set on to form a difference vectors such that each difference vector stores the corresponding difference between the individual phase values for all the subjects from CD/ED/MD with respect to it's corresponding ND session's values.

2.1 Data Interpretation

The data obtained in all the difference vectors are to be plotted using a box plots to visually guess how are the means of each session's signal sets phases are varying with it's corresponding phases. Our initial thoughts on this interpretation would be that the stressed out phases (phases 2 and 4) might show much deviation than it's corresponding non stressed phases (phases 1,3 and 5). These box plots of all the phases are plotted with CD/ED/MD on y-axis and ND on x-axis.

NOTE:All the operations being performed is on the existing cleaned data sets, the cleaned dataset obtained from Homework 1 with a revised range on Heart Rate [40,120].

Data Complications: We have observed that certain phase values (for example, in MD session of Breathing rate/PEDA/PP), it has been observed that NAN values have been reported and this is mainly due to the fact that certain subjects did not receive that part of time slice, so we figured out a possible solution to get rid of this errors by rooting out the corresponding ND values of the missing time slice in MD session's signal set's phase values.This implies that there will be a subject drop for such scenario as we are missing out on an entire set of phase values.So, we decided to drop the corresponding ND values if there are missing full phase values in any of the sessions CD/ED/MD.

3 Breathing Rate Observations

Before Proceeding any further with the data difference vectors obtained, we have to check for normality and also all the assumptions to carry out a paired t-test on.

Various assumptions to carry out a successful paired t-test:
1. The dependent variable must be continuous and not discrete.
2. The observations are to be independent of each other.
3. The dependent variable should be approximately distributed.
4. The dependent variable should not contain any outliers.

NOTE: In case if the data is not normally distributed which can be tested using a QQ-plot/ Histogram/Shapiro-Wilks test. We are to apply any of the correction measures like Log,1/n, adding a constant to bring it to normal distribution.

Exceptions: Even after applying corrections, we observe non normality in the distribution we have to then proceed on with conducting non parametric tests on the non-normal data.

If it does obey normal distribution after correction factors,then a paired t-test should be run on the corrected data and not on the original data.

Phase Normality distributions:

Phase 1:The Difference vector obtained from CD-ND phase 1 on which the normality test is being done.

```
> shapiro.test(diffvectorph1CD)

        Shapiro-Wilk normality test

data:  diffvectorph1CD
W = 0.95987, p-value = 0.03376
```

Figure 1: Normality test for phase 1 CD vs ND Breathing Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 2:The Difference vector obtained from CD-ND phase 2 on which the normality test is being done.

```
> shapiro.test(diffvectorph2CD)

        Shapiro-Wilk normality test

data:  diffvectorph2CD
W = 0.97246, p-value = 0.1555
```

Figure 2: Normality test for phase 2 CD vs ND Breathing Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.
Phase 3:The Difference vector obtained from CD-ND phase 3 on which the normality test is being done.

```
> shapiro.test(diffvectorph3CD)

        Shapiro-Wilk normality test

data:  diffvectorph3CD
W = 0.96694, p-value = 0.07948
```

Figure 3: Normality test for phase 3 CD vs ND Breathing Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.
Phase 4:The Difference vector obtained from CD-ND phase 4 on which the normality test is being done.

```
> shapiro.test(diffvectorph4CD)

        Shapiro-Wilk normality test

data:  diffvectorph4CD
W = 0.9587, p-value = 0.02936
```

Figure 4: Normality test for phase 4 CD vs ND Breathing Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 5:The Difference vector obtained from CD-ND phase 5 on which the normality test is being done.

```
> shapiro.test(diffvectorph5CD)

        Shapiro-Wilk normality test

data:  diffvectorph5CD
W = 0.98679, p-value = 0.7182
```

Figure 5: Normality test for phase 5 CD vs ND Breathing Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.
Phase 1:The Difference vector obtained from ED-ND phase 1 on which the normality test is being done.

```
> shapiro.test(diffvectorph1ED)

        Shapiro-Wilk normality test

data:  diffvectorph1ED
W = 0.94432, p-value = 0.005141
```

Figure 6: Normality test for phase 1 ED vs ND Breathing Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 2:The Difference vector obtained from ED-ND phase 2 on which the normality test is being done.
Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent

```
> shapiro.test(diffvectorph2ED)

        Shapiro-Wilk normality test

data:  diffvectorph2ED
W = 0.98396, p-value = 0.5523
```

Figure 7: Normality test for phase 2 ED vs ND Breathing Rate

confidence interval. Hence we conclude that the **data is normal**.
Phase 3:The Difference vector obtained from ED-ND phase 3 on which the normality test is being done.

```
> shapiro.test(diffvectorph3ED)

        Shapiro-Wilk normality test

data:  diffvectorph3ED
W = 0.95537, p-value = 0.01844
```

Figure 8: Normality test for phase 3 ED vs ND Breathing Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 4:The Difference vector obtained from ED-ND phase 4 on which the normality test is being done.

```
> shapiro.test(diffvectorph4ED)

        Shapiro-Wilk normality test

data:  diffvectorph4ED
W = 0.99047, p-value = 0.8961
```

Figure 9: Normality test for phase 4 ED vs ND Breathing Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Phase 5:The Difference vector obtained from ED-ND phase 5 on which the normality test is being done.

```
> shapiro.test(diffvectorph5ED)

        Shapiro-Wilk normality test

data:  diffvectorph5ED
W = 0.98159, p-value = 0.4332
```

Figure 10: Normality test for phase 5 ED vs ND Breathing Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.
Phase 1:The Difference vector obtained from MD-ND phase 1 on which the normality test is being done.

```
> shapiro.test(diffvectorph1MD)

        Shapiro-Wilk normality test

data:  diffvectorph1MD
W = 0.93297, p-value = 0.00266
```

Figure 11: Normality test for phase 1 MD vs ND Breathing Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 2:The Difference vector obtained from MD-ND phase 2 on which the normality test is being done.

```
> shapiro.test(diffvectorph2MD)

        Shapiro-Wilk normality test

data:  diffvectorph2MD
W = 0.96584, p-value = 0.09115
```

Figure 12: Normality test for phase 2 MD vs ND Breathing Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.
Phase 3:The Difference vector obtained from MD-ND phase 3 on which the normality test is being done.
Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent

```
> shapiro.test(diffvectorph3MD)

        Shapiro-Wilk normality test

data:  diffvectorph3MD
W = 0.9349, p-value = 0.003224
```

Figure 13: Normality test for phase 3 MD vs ND Breathing Rate

confidence interval. Hence we conclude that the **data is not normal**.
Phase 4:The Difference vector obtained from MD-ND phase 4 on which the normality test is being done.

```
> shapiro.test(diffvectorph4MD)

        Shapiro-Wilk normality test

data:  diffvectorph4MD
W = 0.98073, p-value = 0.4601
```

Figure 14: Normality test for phase 4 MD vs ND Breathing Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.
Phase 5:The Difference vector obtained from MD-ND phase 5 on which the normality test is being done.

```
> shapiro.test(diffvectorph5MD)

        Shapiro-Wilk normality test

data:  diffvectorph5MD
W = 0.97852, p-value = 0.3803
```

Figure 15: Normality test for phase 5 MD vs ND Breathing Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Q Q plot to check Normal Distributions for Breathing Rate:

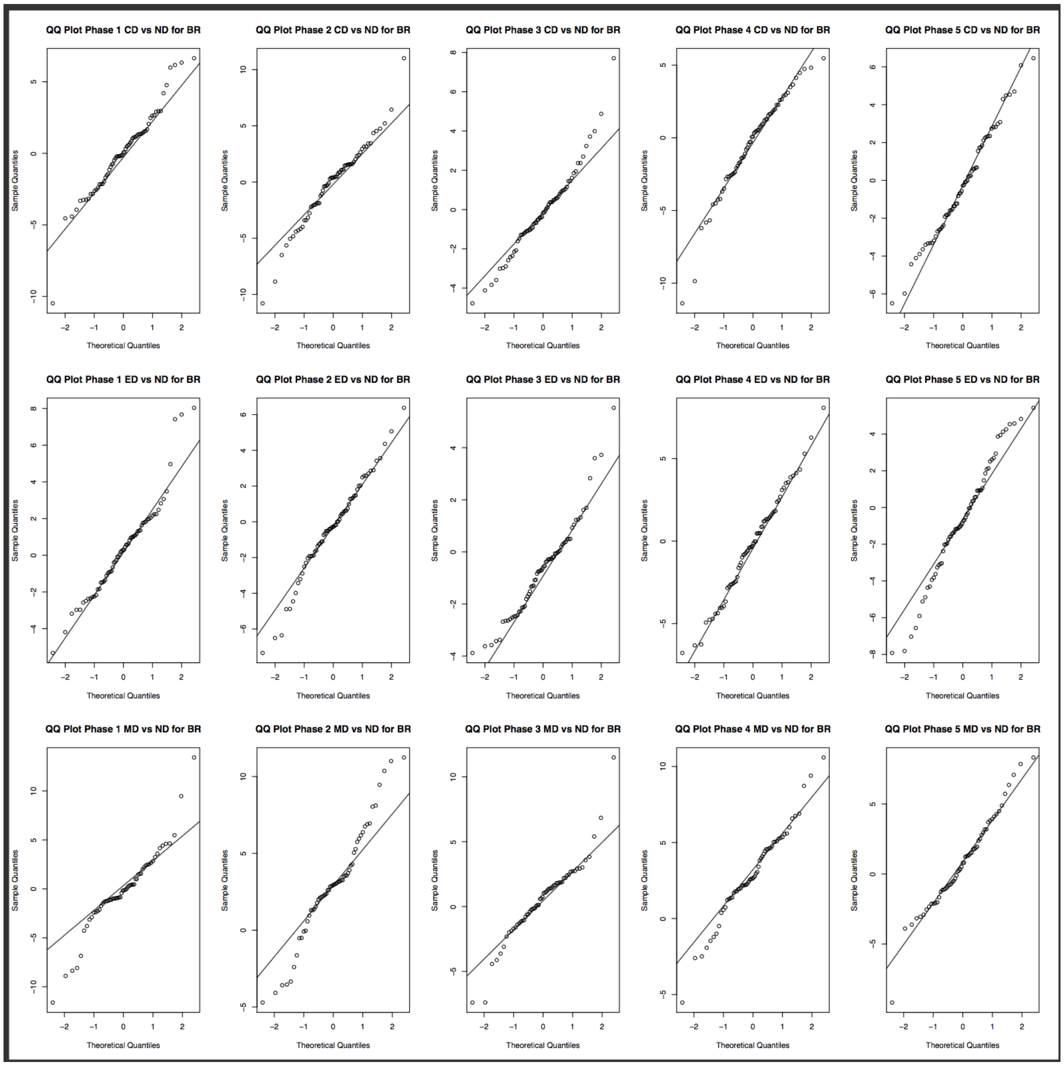


Figure 16: QQ plots for Breathing Rate

We observe that from the QQ plots for Breathing rate all of it's sessions and it's phases, most of the data points are observing normal data but there are few outliers (3 to 4) which can be attributed to that these rogue points on the fringes do not represent the distribution, and in all likelihood is noise, which if we done a much deeper quality control, would have found and could have discarded them.

3.1 Tests

Now, after observing normality in distribution in almost all of breathing rate phases in all the sessions, we proceed on to carrying a t-test on the difference vector obtained.

Null Hypothesis: There is no significant difference in the means of respective phases between Breathing Rates

Alternate Hypothesis: There is a significant difference in the means of respective phases between Breathing Rates

Phase1 CD-ND BR t-test:

```
> t.test(diffvectorph1CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1CD
t = 0.17354, df = 64, p-value = 0.8628
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.6597727  0.7853015
sample estimates:
mean of x
0.0627644
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase2 CD-ND BR t-test:

```
> t.test(diffvectorph2CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2CD
t = -0.22954, df = 64, p-value = 0.8192
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.9854517  0.7823303
sample estimates:
 mean of x
-0.1015607
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase3 CD-ND BR t-test:

```
> t.test(diffvectorph3CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3CD
t = -0.35101, df = 64, p-value = 0.7267
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.6343995  0.4447820
sample estimates:
  mean of x
-0.09480878
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase4 CD-ND BR t-test:

```
> t.test(diffvectorph4CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4CD
t = -1.0237, df = 64, p-value = 0.3099
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -1.2468425  0.4019764
sample estimates:
 mean of x
-0.4224331
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase5 CD-ND BR t-test:

```
> t.test(diffvectorph5CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5CD
t = -0.63938, df = 64, p-value = 0.5249
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.9199322  0.4738502
sample estimates:
mean of x
-0.223041
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase1 ED-ND BR t-test:

```
> t.test(diffvectorph1ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1ED
t = 1.1021, df = 65, p-value = 0.2745
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.2791442  0.9666417
sample estimates:
mean of x
0.3437487
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase2 ED-ND BR t-test:

```
> t.test(diffvectorph2ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2ED
t = -0.92862, df = 65, p-value = 0.3565
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.9648186  0.3523607
sample estimates:
mean of x
-0.306229
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase3 ED-ND BR t-test:

```
> t.test(diffvectorph3ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3ED
t = -2.874, df = 65, p-value = 0.005472
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -1.090643 -0.196323
sample estimates:
 mean of x
-0.6434831
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.

Phase4 ED-ND BR t-test:

```
> t.test(diffvectorph4ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4ED
t = -0.55602, df = 65, p-value = 0.5801
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.9884473  0.5579246
sample estimates:
 mean of x
-0.2152614
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase5 ED-ND BR t-test:

```
> t.test(diffvectorph5ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5ED
t = -1.757, df = 65, p-value = 0.08363
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -1.45076469  0.09280579
sample estimates:
 mean of x
-0.6789795
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase1 MD-ND BR t-test:

```
> t.test(diffvectorph1MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1MD
t = -0.1987, df = 59, p-value = 0.8432
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -1.1350948  0.9300288
sample estimates:
mean of x
-0.102533
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase2 MD-ND BR t-test:

```
> t.test(diffvectorph2MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2MD
t = 6.5372, df = 59, p-value = 1.635e-08
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 2.065962 3.888621
sample estimates:
mean of x
 2.977291
```

we observe that p-value is less than alpha (0.05),hence we accept the null hypothesis, there is **significant difference in the means**.
Phase3 MD-ND BR t-test:

```
> t.test(diffvectorph3MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3MD
t = 1.4697, df = 59, p-value = 0.147
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.2035054  1.3293773
sample estimates:
mean of x
0.5629359
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase4 MD-ND BR t-test:

```
> t.test(diffvectorph4MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4MD
t = 7.8353, df = 59, p-value = 1.039e-10
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 2.213398 3.731653
sample estimates:
mean of x 
 2.972526 
```

we observe that p-value is less than alpha (0.05),hence we accept the null hypothesis, there is **significant difference in the means**.
Phase5 MD-ND BR t-test:

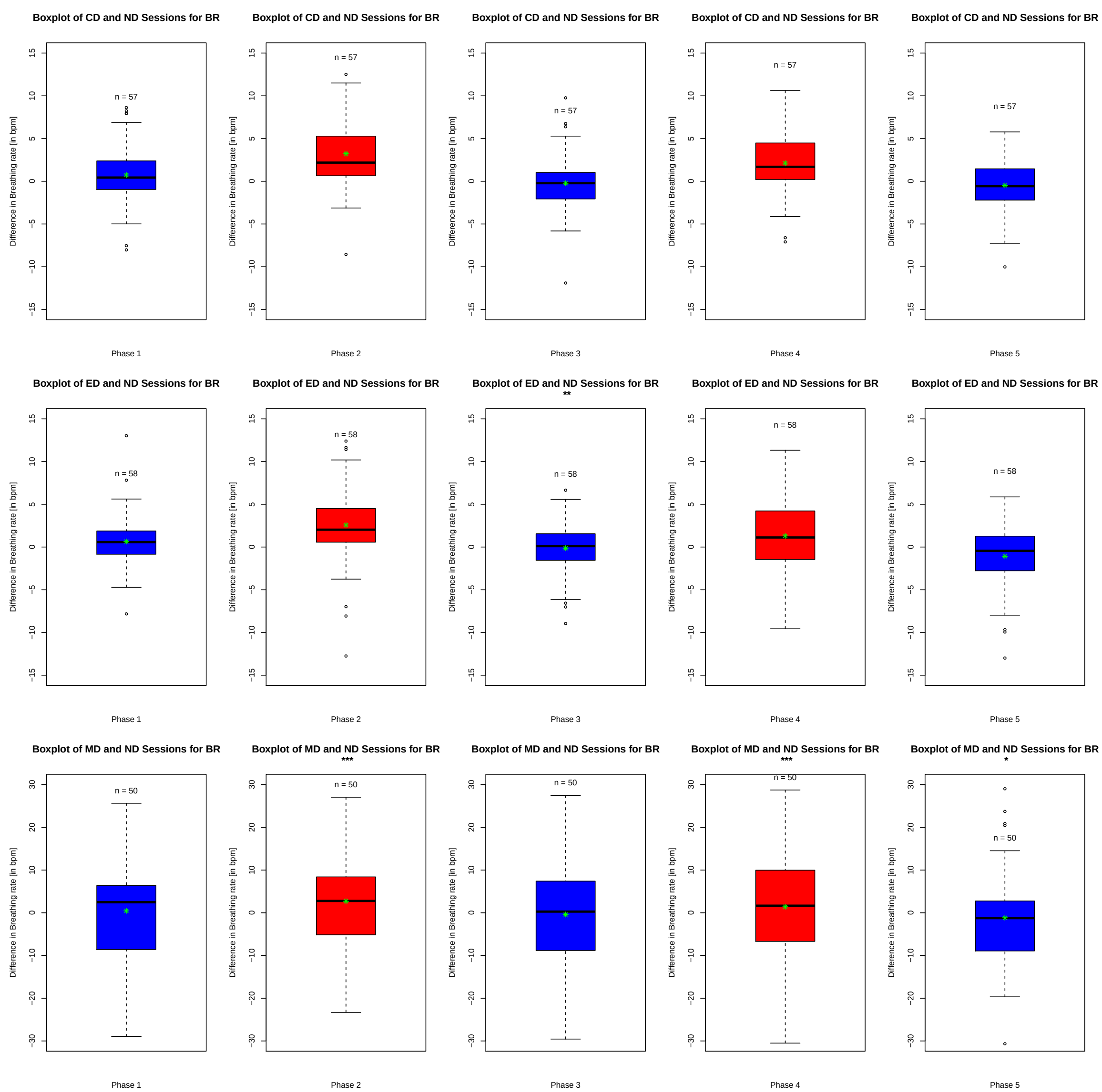
```
> t.test(diffvectorph5MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5MD
t = 2.0295, df = 58, p-value = 0.047
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.01155151 1.67480841
sample estimates:
mean of x 
  0.84318 
```

we observe that p-value is less than alpha (0.05),hence we accept the null hypothesis, there is **significant difference in the means**.

Box Plot of all phases all sessions BR:



4 Heart Rate Observations

Before Proceeding any further with the data difference vectors obtained, we have to check for normality and also all the assumptions to carry out a paired t-test on.
Various assumptions to carry out a successful paired t-test:
1. The dependent variable must be continuous and not discrete.
2. The observations are to be independent of each other.
3. The dependent variable should be approximately distributed.
4. The dependent variable should not contain any outliers.

NOTE: In case if the data is not normally distributed which can be tested using a QQ-plot/ Histogram/Shapiro-Wilks test. We are to apply any of the correction measures like Log,1/n, adding a constant to bring it to normal distribution.
Exceptions: Even after applying corrections, we observe non normality in the distribution we have to then proceed on with conducting non parametric tests on the non-normal data.
If it does obey normal distribution after correction factors,then a paired t-test should be run on the corrected data and not on the original data.
Phase Normality distributions:
Phase 1:The Difference vector obtained from CD-ND phase 1 Heart Rate on which the normality test is being done.

```
> shapiro.test(diffvectorph1CD)

        Shapiro-Wilk normality test

data:  diffvectorph1CD
W = 0.9668, p-value = 0.1189
```

Figure 17: Normality test for phase 1 CD vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Phase 2:The Difference vector obtained from CD-ND phase 2 on which the normality test is being done.

```
> shapiro.test(diffvectorph2CD)

        Shapiro-Wilk normality test

data:  diffvectorph2CD
W = 0.96516, p-value = 0.0995
```

Figure 18: Normality test for phase 2 CD vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.
Phase 3:The Difference vector obtained from CD-ND phase 3 on which the normality test is being done.

```
> shapiro.test(diffvectorph3CD)

        Shapiro-Wilk normality test

data:  diffvectorph3CD
W = 0.95555, p-value = 0.03531
```

Figure 19: Normality test for phase 3 CD vs ND Heart Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 4:The Difference vector obtained from CD-ND phase 4 on which the normality test is being done.

```
> shapiro.test(diffvectorph4CD)

        Shapiro-Wilk normality test

data:  diffvectorph4CD
W = 0.98128, p-value = 0.5202
```

Figure 20: Normality test for phase 4 CD vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Phase 5:The Difference vector obtained from CD-ND phase 5 on which the normality test is being done.

```
> shapiro.test(diffvectorph5CD)

        Shapiro-Wilk normality test

data:  diffvectorph5CD
W = 0.97849, p-value = 0.4019
```

Figure 21: Normality test for phase 5 CD vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Phase 1:The Difference vector obtained from ED-ND phase 1 on which the normality test is being done.

```
> shapiro.test(diffvectorph1ED)

        Shapiro-Wilk normality test

data:  diffvectorph1ED
W = 0.93559, p-value = 0.004177
```

Figure 22: Normality test for phase 1 ED vs ND Heart Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is Not normal**.

Phase 2:The Difference vector obtained from ED-ND phase 1 on which the normality test is being done.

```
> shapiro.test(diffvectorph2ED)

        Shapiro-Wilk normality test

data:  diffvectorph2ED
W = 0.96295, p-value = 0.07382
```

Figure 23: Normality test for phase 2 ED vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent

confidence interval. Hence we conclude that the **data is normal**.
Phase 3:The Difference vector obtained from ED-ND phase 3 on which the normality test is being done.

```
> shapiro.test(diffvectorph3ED)

        Shapiro-Wilk normality test

data:  diffvectorph3ED
W = 0.97526, p-value = 0.2814
```

Figure 24: Normality test for phase 3 ED vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Phase 4:The Difference vector obtained from ED-ND phase 4 on which the normality test is being done.

```
> shapiro.test(diffvectorph4ED)

        Shapiro-Wilk normality test

data:  diffvectorph4ED
W = 0.99187, p-value = 0.9652
```

Figure 25: Normality test for phase 4 ED vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Phase 5:The Difference vector obtained from ED-ND phase 5 on which the normality test is being done.

```
> shapiro.test(diffvectorph5ED)

        Shapiro-Wilk normality test

data:  diffvectorph5ED
W = 0.94824, p-value = 0.01512
```

Figure 26: Normality test for phase 5 ED vs ND Heart Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is Not normal**.

Phase 1:The Difference vector obtained from MD-ND phase 1 on which the normality test is being done.

```
> shapiro.test(diffvectorph1MD)

        Shapiro-Wilk normality test

data:  diffvectorph1MD
W = 0.95281, p-value = 0.04454
```

Figure 27: Normality test for phase 1 MD vs ND Heart Rate

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is Not normal**.

Phase 2:The Difference vector obtained from MD-ND phase 2 on which the normality test is being done.

```
> shapiro.test(diffvectorph2MD)

        Shapiro-Wilk normality test

data:  diffvectorph2MD
W = 0.96736, p-value = 0.1805
```

Figure 28: Normality test for phase 2 MD vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is Not normal**.

Phase 3:The Difference vector obtained from MD-ND phase 3 on which the normality test is being done.

```
> shapiro.test(diffvectorph3MD)

        Shapiro-Wilk normality test

data:  diffvectorph3MD
W = 0.98053, p-value = 0.5744
```

Figure 29: Normality test for phase 3 MD vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Phase 4:The Difference vector obtained from MD-ND phase 4 on which the normality test is being done.

```
> shapiro.test(diffvectorph4MD)

        Shapiro-Wilk normality test

data:  diffvectorph4MD
W = 0.97979, p-value = 0.5432
```

Figure 30: Normality test for phase 4 MD vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Phase 5:The Difference vector obtained from MD-ND phase 5 on which the normality test is being done.

```
> shapiro.test(diffvectorph5MD)

        Shapiro-Wilk normality test

data:  diffvectorph5MD
W = 0.96874, p-value = 0.2056
```

Figure 31: Normality test for phase 5 MD vs ND Heart Rate

Here we observe that p-value obtained is greater than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is normal**.

Q Q plot to check Normal Distributions for Heart Rate:

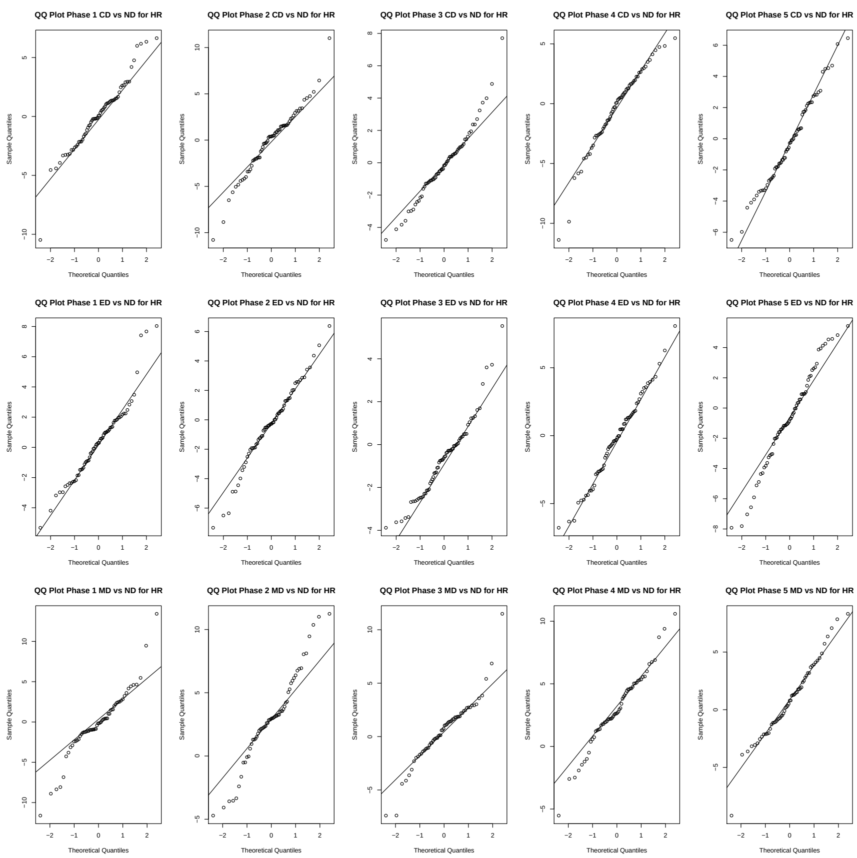


Figure 32: QQ plots for Heart Rate

We observe that from the QQ plots for Breathing rate all of it's sessions and it's phases, most of the data points are observing normal data but there are few outliers (3 to 4) which can be attributed to that these rogue points on the fringes do not represent the distribution, and in all likelihood is noise, which if we done a much deeper quality control, would have found and could have discarded them.

4.1 Tests

Now, after observing normality in distribution in almost all of Heart rate phases in all the sessions, we proceed on to carrying a t-test on the difference vector obtained.
Null Hypothesis: There is no significant difference in the means of respective phases between Heart Rates
Alternate Hypothesis: There is a significant difference in the means of respective phases between Heart Rates
Phase1 CD-ND HR t-test:

```
> t.test(diffvectorph1CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1CD
t = 1.5672, df = 56, p-value = 0.1227
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.2045851  1.6750810
sample estimates:
mean of x
0.7352479
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.
Phase2 CD-ND HR t-test:

```
> t.test(diffvectorph2CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2CD
t = 6.092, df = 56, p-value = 1.076e-07
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 2.164345 4.285125
sample estimates:
mean of x
 3.224735
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.
Phase3 CD-ND HR t-test:

```
> t.test(diffvectorph3CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3CD
t = -0.51567, df = 56, p-value = 0.6081
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -1.1319682  0.6684954
sample estimates:
 mean of x
-0.2317364
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.
Phase4 CD-ND HR t-test:

```
> t.test(diffvectorph4CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4CD
t = 4.13, df = 56, p-value = 0.0001221
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 1.094355 3.155915
sample estimates:
mean of x
 2.125135
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.

Phase5 CD-ND HR t-test:

```
> t.test(diffvectorph5CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5CD
t = -1.2228, df = 56, p-value = 0.2265
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -1.2674004  0.3065932
sample estimates:
 mean of x
-0.4804036
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase1 ED-ND HR t-test:

```
> t.test(diffvectorph1ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1ED
t = 1.5507, df = 57, p-value = 0.1265
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.1876648  1.4761014
sample estimates:
mean of x
0.6442183
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase2 ED-ND HR t-test:

```
> t.test(diffvectorph2ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2ED
t = 3.7961, df = 57, p-value = 0.0003584
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 1.216176 3.931700
sample estimates:
mean of x
 2.573938
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.
Phase3 ED-ND HR t-test:

```
> t.test(diffvectorph3ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3ED
t = -0.34255, df = 57, p-value = 0.7332
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.9538929  0.6752102
sample estimates:
 mean of x
-0.1393414
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase4 ED-ND HR t-test:

```
> t.test(diffvectorph4ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4ED
t = 2.2144, df = 57, p-value = 0.03082
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.1248454 2.4844145
sample estimates:
mean of x
  1.30463
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.
Phase5 ED-ND HR t-test:

```
> t.test(diffvectorph5ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5ED
t = -2.0969, df = 57, p-value = 0.04045
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -2.12361528 -0.04893205
sample estimates:
mean of x
-1.086274
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.

Phase1 MD-ND HR t-test:

```
> t.test(diffvectorph1MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1MD
t = 0.26302, df = 49, p-value = 0.7936
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -2.994317  3.896171
sample estimates:
mean of x
0.4509272
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase2 MD-ND HR t-test:

```
> t.test(diffvectorph2MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2MD
t = 1.564, df = 49, p-value = 0.1242
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.766775  6.150253
sample estimates:
mean of x
 2.691739
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase3 MD-ND HR t-test:

```
> t.test(diffvectorph3MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3MD
t = -0.22912, df = 49, p-value = 0.8197
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -3.941094  3.134379
sample estimates:
 mean of x
-0.4033572
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase4 MD-ND HR t-test:

```
> t.test(diffvectorph4MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4MD
t = 0.81413, df = 49, p-value = 0.4195
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -2.074458  4.899956
sample estimates:
mean of x
 1.412749
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase5 MD-ND HR t-test:

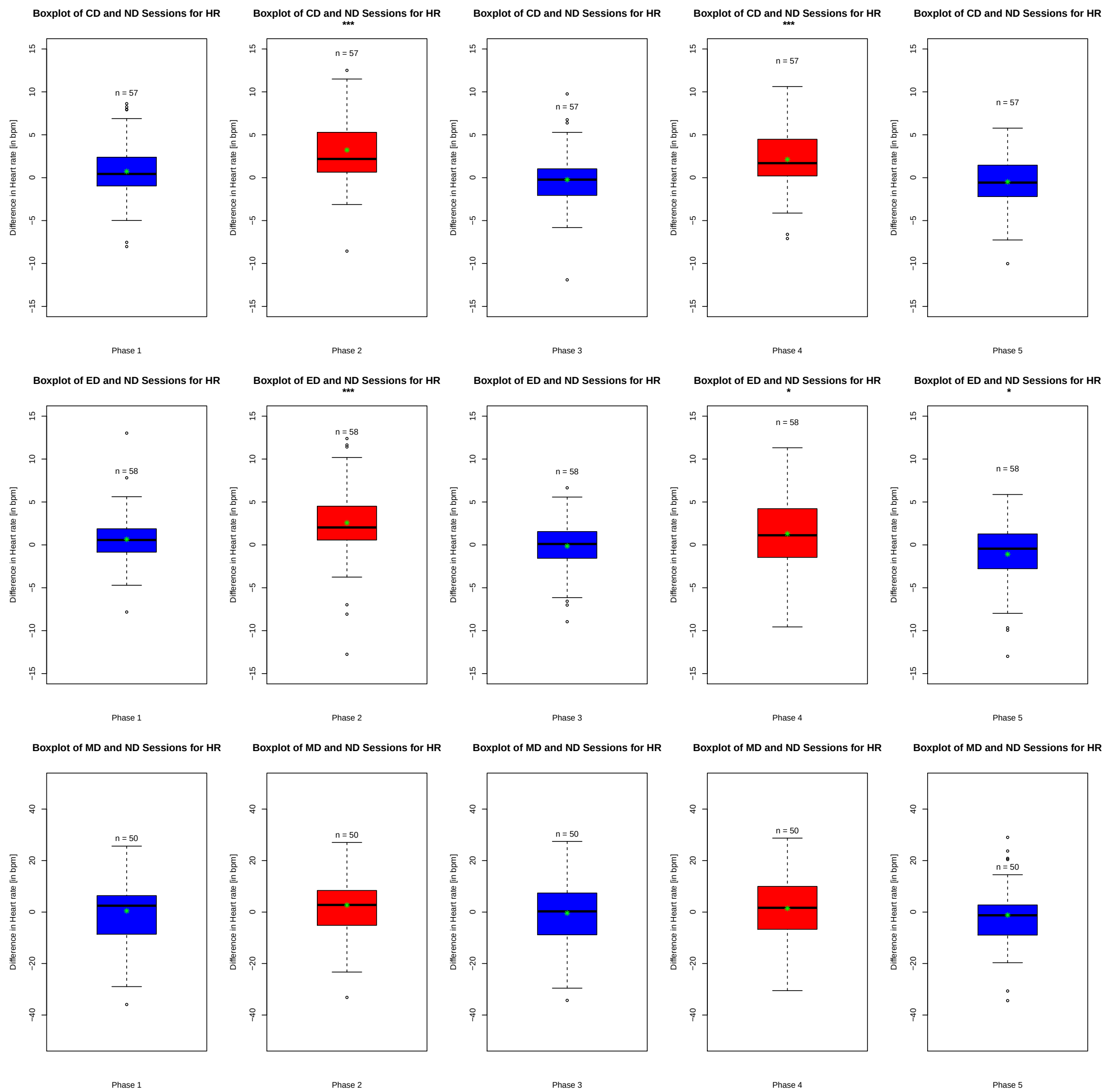
```
> t.test(diffvectorph5CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5CD
t = -1.2228, df = 56, p-value = 0.2265
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -1.2674004  0.3065932
sample estimates:
 mean of x
-0.4804036
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Box Plot of all phases all sessions HR:



5 Palm EDA (PEDA) Observations

Before Proceeding any further with the data difference vectors obtained, we have to check for normality and also all the assumptions to carry out a paired t-test on.
Various assumptions to carry out a successful paired t-test:
1. The dependent variable must be continuous and not discrete.
2. The observations are to be independent of each other.
3. The dependent variable should be approximately distributed.
4. The dependent variable should not contain any outliers.

NOTE: In case if the data is not normally distributed which can be tested using a QQ-plot/ Histogram/Shapiro-Wilks test. We are to apply any of the correction measures like Log,1/n, adding a constant to bring it to normal distribution.
Exceptions: Even after applying corrections, we observe non normality in the distribution we have to then proceed on with conducting non parametric tests on the non-normal data.
If it does obey normal distribution after correction factors,then a paired t-test should be run on the corrected data and not on the original data.
Phase 1:The Difference vector obtained from CD-ND phase 1 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph1CD)

        Shapiro-Wilk normality test

data:  diffvectorph1CD
W = 0.54971, p-value = 7.56e-12
```

Figure 33: Normality test for phase 1 CD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 2:The Difference vector obtained from CD-ND phase 2 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph2CD)

        Shapiro-Wilk normality test

data:  diffvectorph2CD
W = 0.657, p-value = 3.581e-10
```

Figure 34: Normality test for phase 2 CD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 3:The Difference vector obtained from CD-ND phase 3 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph3CD)

        Shapiro-Wilk normality test

data:  diffvectorph3CD
W = 0.75107, p-value = 2.196e-08
```

Figure 35: Normality test for phase 3 CD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 4:The Difference vector obtained from CD-ND phase 4 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph4CD)

        Shapiro-Wilk normality test

data:  diffvectorph4CD
W = 0.81624, p-value = 7.085e-07
```

Figure 36: Normality test for phase 4 CD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 5:The Difference vector obtained from CD-ND phase 5 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph5CD)

        Shapiro-Wilk normality test

data:  diffvectorph5CD
W = 0.75114, p-value = 2.205e-08
```

Figure 37: Normality test for phase 5 CD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 1:The Difference vector obtained from ED-ND phase 1 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph1ED)

        Shapiro-Wilk normality test

data:  diffvectorph1ED
W = 0.56937, p-value = 2.435e-11
```

Figure 38: Normality test for phase 1 ED vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 2:The Difference vector obtained from ED-ND phase 2 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph2ED)

        Shapiro-Wilk normality test

data:  diffvectorph2ED
W = 0.58371, p-value = 3.954e-11
```

Figure 39: Normality test for phase 2 ED vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 3:The Difference vector obtained from ED-ND phase 3 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph3ED)

        Shapiro-Wilk normality test

data:  diffvectorph3ED
W = 0.45131, p-value = 6.518e-13
```

Figure 40: Normality test for phase 3 ED vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 4:The Difference vector obtained from ED-ND phase 4 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph4ED)

        Shapiro-Wilk normality test

data:  diffvectorph4ED
W = 0.47422, p-value = 1.256e-12
```

Figure 41: Normality test for phase 4 ED vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 5:The Difference vector obtained from ED-ND phase 5 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph5ED)

        Shapiro-Wilk normality test

data:  diffvectorph5ED
W = 0.49743, p-value = 2.495e-12
```

Figure 42: Normality test for phase 5 ED vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 1:The Difference vector obtained from MD-ND phase 1 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph1MD)

        Shapiro-Wilk normality test

data:  diffvectorph1MD
W = 0.70297, p-value = 3.954e-08
```

Figure 43: Normality test for phase 1 MD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 2:The Difference vector obtained from MD-ND phase 2 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph2MD)

        Shapiro-Wilk normality test

data:  diffvectorph2MD
W = 0.7183, p-value = 7.318e-08
```

Figure 44: Normality test for phase 2 MD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 3:The Difference vector obtained from MD-ND phase 3 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph3MD)

        Shapiro-Wilk normality test

data:  diffvectorph3MD
W = 0.70632, p-value = 4.516e-08
```

Figure 45: Normality test for phase 3 MD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 4:The Difference vector obtained from MD-ND phase 4 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph4MD)

        Shapiro-Wilk normality test

data:  diffvectorph4MD
W = 0.69975, p-value = 3.483e-08
```

Figure 46: Normality test for phase 4 MD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 5:The Difference vector obtained from MD-ND phase 5 PEDA on which the normality test is being done.

```
> shapiro.test(diffvectorph5MD)

        Shapiro-Wilk normality test

data:  diffvectorph5MD
W = 0.72339, p-value = 9.022e-08
```

Figure 47: Normality test for phase 5 MD vs ND PEDA

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Q Q plot to check Normal Distributions for PEDA:
We observe that from the QQ plots for PEDA all of it's sessions and it's phases, most of the data points are observing normal data but there are few outliers (3 to 4) which can be attributed to that these rogue points on the fringes do not represent the distribution, and in all likelihood is noise, which if we done a much deeper quality control, would have found and could have discarded them.So through QQ plots it can be said that this data is obeying normal distribution and can thus proceed on with conducting t-tests without any corrections on the data set.

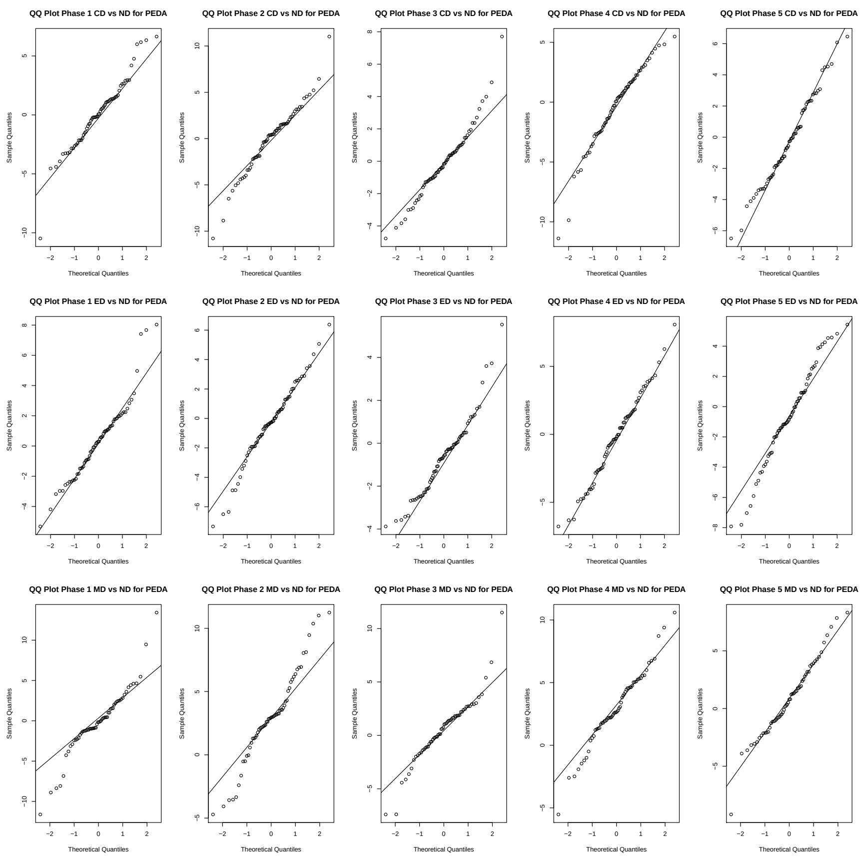


Figure 48: QQ plots for PEDA

Comments: The big contradiction between shapiro Wilks test showing non normal data distribution and QQ plots showing normal distribution in almost all of the phases of CD,MD and ED vs ND in PEDA can be attributed to those extremely far outliers/fringe points that might be hampering shapiro wilks results and thus making it appear non normal. Hence QQ plots here can be considered as a clear indicator of data obeying normal distribution and hence t-tests can be conducted without any sort of error [log] corrections. It appears that Phases 1 and 2 of MD vs ND appear to obey non normal distribution and hence a log transformation is necessary for the said phases.

5.1 Tests

Now, after observing normality in distribution in almost all of PEDA phases in all the sessions, we proceed on to carrying a t-test on the difference vector obtained.

Null Hypothesis: There is no significant difference in the means of respective phases between PEDA values.
Alternate Hypothesis: There is a significant difference in the means of respective phases between PEDA values.
Phase1 CD-ND PEDA t-test:

```
> t.test(diffvectorph1CD,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1CD
t = -0.17746, df = 55, p-value = 0.8598
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -48.88347  40.93019
sample estimates:
mean of x
-3.976639
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.
Phase2 CD-ND PEDA t-test:

```
> t.test(diffvectorph2CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2CD
t = -0.53992, df = 55, p-value = 0.5914
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -49.30390  28.37592
sample estimates:
mean of x
-10.46399
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase3 CD-ND PEDA t-test:

```
> t.test(diffvectorph3CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3CD
t = 0.40641, df = 55, p-value = 0.686
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -26.15928  39.46833
sample estimates:
mean of x
 6.654522
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase4 CD-ND PEDA t-test:

```
> t.test(diffvectorph4CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4CD
t = -0.75711, df = 55, p-value = 0.4522
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -53.76448  24.28007
sample estimates:
mean of x
 -14.7422
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase5 CD-ND PEDA t-test:

```
> t.test(diffvectorph5CD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5CD
t = -0.55729, df = 55, p-value = 0.5796
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -53.13883  30.01514
sample estimates:
mean of x
-11.56185
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase1 ED-ND PEDA t-test:

```
> t.test(diffvectorph1ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1ED
t = -1.5469, df = 53, p-value = 0.1278
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -83.69949  10.81127
sample estimates:
mean of x
-36.44411
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase2 ED-ND PEDA t-test:

```
> t.test(diffvectorph2ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2ED
t = -1.9754, df = 53, p-value = 0.05344
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -104.5802392    0.7967014
sample estimates:
mean of x
-51.89177
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.
Phase3 ED-ND PEDA t-test:

```
> t.test(diffvectorph3ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3ED
t = -2.0023, df = 53, p-value = 0.05038
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -117.8240732    0.1008857
sample estimates:
mean of x
-58.86159
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase4 ED-ND PEDA t-test:

```
> t.test(diffvectorph4ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4ED
t = -1.8569, df = 53, p-value = 0.06888
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -108.814186    4.191852
sample estimates:
mean of x
-52.31117
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase5 ED-ND PEDA t-test:

```
> t.test(diffvectorph5ED, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5ED
t = -1.9308, df = 53, p-value = 0.05886
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -100.144706    1.906149
sample estimates:
mean of x
-49.11928
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase1 MD-ND PEDA t-test:

```
> diffvectorph1MDT = log(diffvectorph1MD-min(diffvectorph1MD)+1)
> t.test(diffvectorph1MDT,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1MDT
t = 41.492, df = 43, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 6.669432 7.350885
sample estimates:
mean of x
 7.010158
```

we observe that p-value is **less** than alpha (0.05),hence we accept the null hypothesis, there is **significant difference in the means**.

Phase2 MD-ND PEDA t-test:

```
> diffvectorph2MDT = log(diffvectorph2MD-min(diffvectorph2MD)+1)
> t.test(diffvectorph2MDT,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2MDT
t = 41.728, df = 43, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 6.692347 7.372076
sample estimates:
mean of x
 7.032211
```

we observe that p-value is **less** than alpha (0.05),hence we accept the null hypothesis, there is **significant difference in the means**.
Phase3 MD-ND PEDA t-test:

```
> t.test(diffvectorph3MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3MD
t = -0.53564, df = 43, p-value = 0.595
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -137.64785   79.87323
sample estimates:
mean of x
-28.88731
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.
Phase4 MD-ND PEDA t-test:

```
> t.test(diffvectorph4MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4MD
t = -0.55359, df = 43, p-value = 0.5827
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -149.65366   85.18816
sample estimates:
mean of x
-32.23275
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase5 MD-ND PEDA t-test:

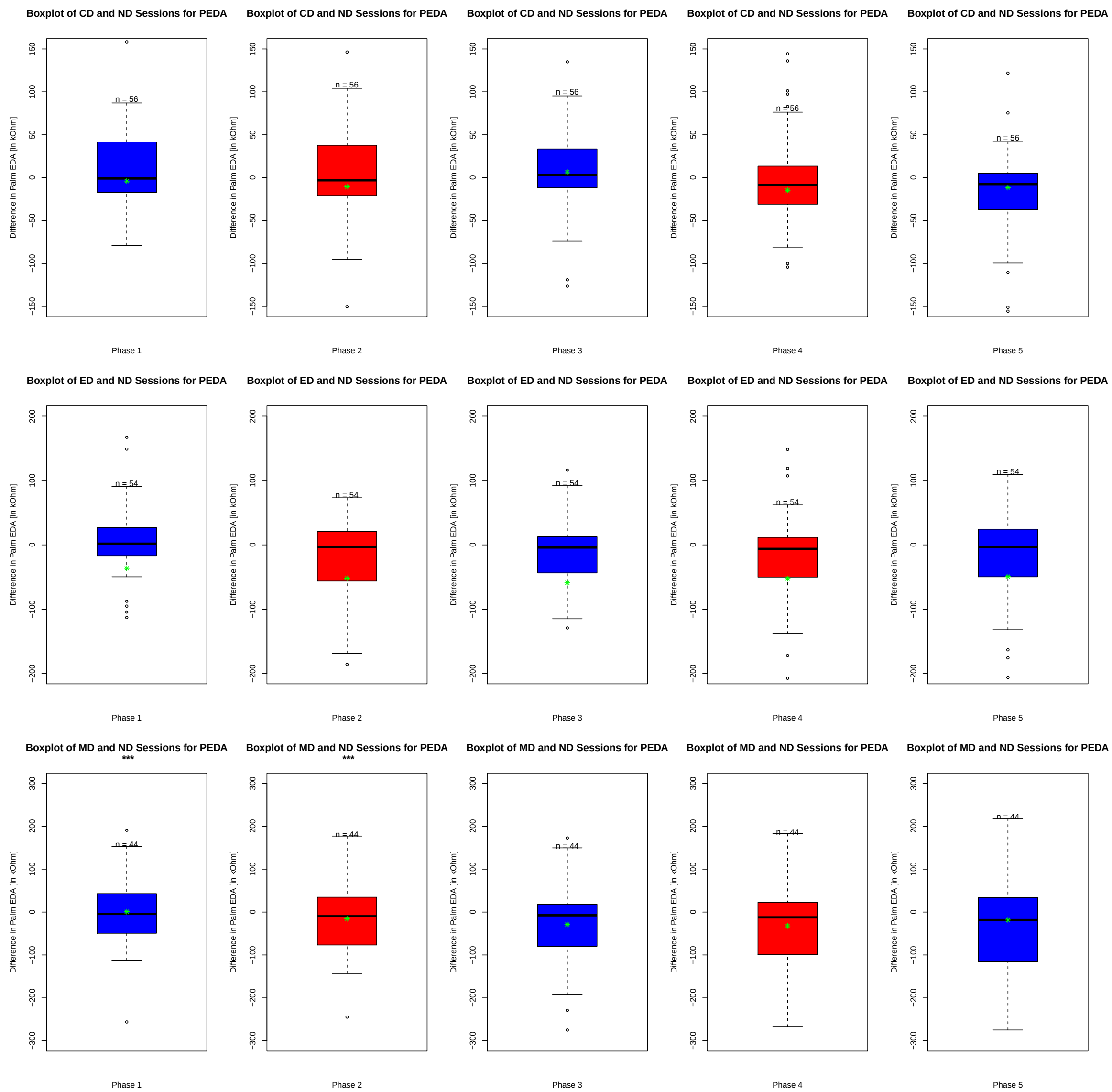
```
> t.test(diffvectorph5MD, conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5MD
t = -0.31528, df = 43, p-value = 0.7541
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -137.6269  100.4126
sample estimates:
mean of x
-18.60717
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Box Plot of all phases all sessions PEDA:



6 PP Perinasal EDA Observations

Before Proceeding any further with the data difference vectors obtained, we have to check for normality and also all the assumptions to carry out a paired t-test on.
Various assumptions to carry out a successful paired t-test:
1. The dependent variable must be continuous and not discrete.
2. The observations are to be independent of each other.
3. The dependent variable should be approximately distributed.
4. The dependent variable should not contain any outliers.
NOTE: In case if the data is not normally distributed which can be tested using a QQ-plot/ Histogram/Shapiro-Wilks test. We are to apply any of the correction measures like Log,1/n, adding a constant to bring it to normal distribution.
Exceptions: Even after applying corrections, we observe non normality in the distribution we have to then proceed on with conducting non parametric tests on the non-normal data.
If it does obey normal distribution after correction factors,then a paired t-test should be run on the corrected data and not on the original data.

Phase 1:The Difference vector obtained from CD-ND phase 1 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph1CD)

        Shapiro-Wilk normality test

data:  diffvectorph1CD
W = 0.87164, p-value = 1.631e-05
```

Figure 49: Normality test for phase 1 CD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 2:The Difference vector obtained from CD-ND phase 2 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph2CD)

        Shapiro-Wilk normality test

data:  diffvectorph2CD
W = 0.82833, p-value = 8.748e-07
```

Figure 50: Normality test for phase 2 CD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 3:The Difference vector obtained from CD-ND phase 3 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph3CD)

        Shapiro-Wilk normality test

data:  diffvectorph3CD
W = 0.87064, p-value = 1.516e-05
```

Figure 51: Normality test for phase 3 CD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 4:The Difference vector obtained from CD-ND phase 4 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph4CD)

        Shapiro-Wilk normality test

data:  diffvectorph4CD
W = 0.82926, p-value = 9.273e-07
```

Figure 52: Normality test for phase 4 CD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 5:The Difference vector obtained from CD-ND phase 5 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph5CD)

        Shapiro-Wilk normality test

data:  diffvectorph5CD
W = 0.85103, p-value = 3.822e-06
```

Figure 53: Normality test for phase 5 CD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 1:The Difference vector obtained from ED-ND phase 1 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph1ED)

        Shapiro-Wilk normality test

data:  diffvectorph1ED
W = 0.92241, p-value = 0.00107
```

Figure 54: Normality test for phase 1 ED vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 2:The Difference vector obtained from ED-ND phase 2 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph2ED)

        Shapiro-Wilk normality test

data:  diffvectorph2ED
W = 0.82092, p-value = 5.542e-07
```

Figure 55: Normality test for phase 2 ED vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 3:The Difference vector obtained from ED-ND phase 3 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph3ED)

        Shapiro-Wilk normality test

data:  diffvectorph3ED
W = 0.75233, p-value = 1.277e-08
```

Figure 56: Normality test for phase 3 ED vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 4:The Difference vector obtained from ED-ND phase 4 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph4ED)

        Shapiro-Wilk normality test

data:  diffvectorph4ED
W = 0.85228, p-value = 4.16e-06
```

Figure 57: Normality test for phase 4 ED vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 5:The Difference vector obtained from ED-ND phase 5 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph5ED)

        Shapiro-Wilk normality test

data:  diffvectorph5ED
W = 0.88063, p-value = 3.195e-05
```

Figure 58: Normality test for phase 5 ED vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 1:The Difference vector obtained from MD-ND phase 1 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph1MD)

        Shapiro-Wilk normality test

data:  diffvectorph1MD
W = 0.84422, p-value = 7.698e-06
```

Figure 59: Normality test for phase 1 MD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 2:The Difference vector obtained from MD-ND phase 2 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph2MD)

        Shapiro-Wilk normality test

data:  diffvectorph2MD
W = 0.83828, p-value = 5.339e-06
```

Figure 60: Normality test for phase 2 MD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Phase 3:The Difference vector obtained from MD-ND phase 3 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph3MD)

        Shapiro-Wilk normality test

data:  diffvectorph3MD
W = 0.84986, p-value = 1.097e-05
```

Figure 61: Normality test for phase 3 MD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 4:The Difference vector obtained from MD-ND phase 4 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph4MD)

        Shapiro-Wilk normality test

data:  diffvectorph4MD
W = 0.86288, p-value = 2.557e-05
```

Figure 62: Normality test for phase 4 MD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.
Phase 5:The Difference vector obtained from MD-ND phase 5 PP on which the normality test is being done.

```
> shapiro.test(diffvectorph5MD)

        Shapiro-Wilk normality test

data:  diffvectorph5MD
W = 0.8861, p-value = 0.0001722
```

Figure 63: Normality test for phase 5 MD vs ND PP

Here we observe that p-value obtained is less than alpha (0.05) ie 95 percent confidence interval. Hence we conclude that the **data is not normal**.

Q Q plot to check Normal Distributions for PP:
We observe that from the QQ plots for PP all of it's sessions and it's phases, most of the data points are observing normal data but there are few outliers (3 to 4) which can be attributed to that these rogue points on the fringes do not represent the distribution, and in all likelihood is noise, which if we done a much deeper quality control, would have found and could have discarded them.So

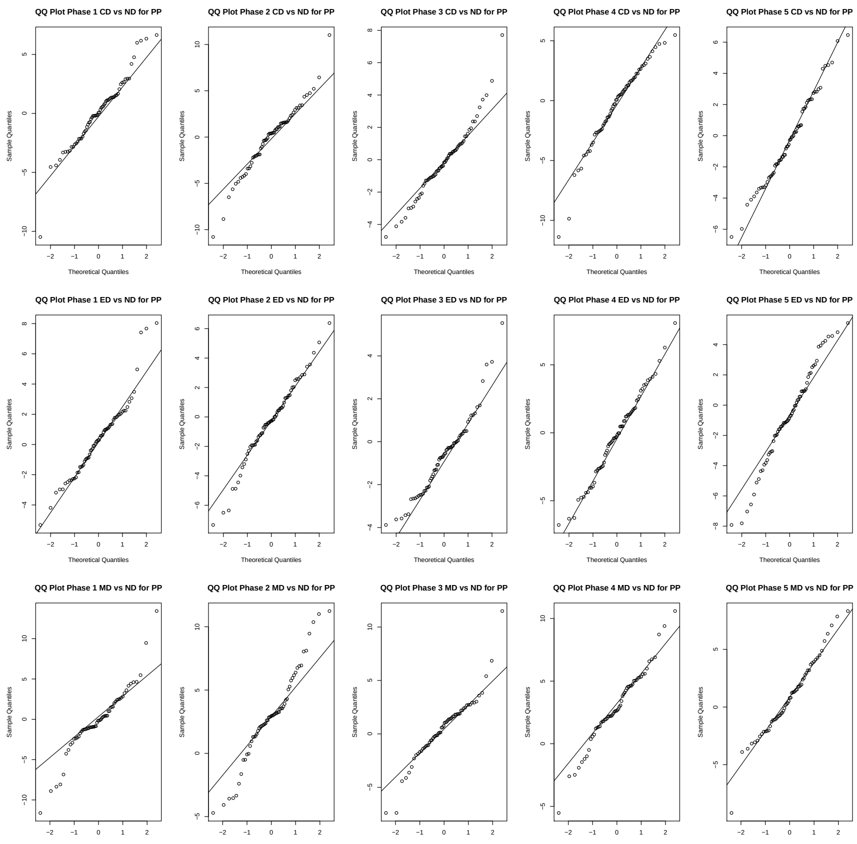


Figure 64: QQ plots for PP

through QQ plots it can be said that this data is obeying normal distribution and can thus proceed on with conducting t-tests without any corrections on the data set.

Comments: The big contradiction between shapiro Wilks test showing non normal data distribution and QQ plots showing normal distribution in almost all of the phases of CD,MD and ED vs ND in PP can be attributed to those extremely far outliers/fringe points that might be hampering shapiro wilks results and thus making it appear non normal. Hence QQ plots here can be considered as a clear indicator of data obeying normal distribution and hence t-tests can be conducted without any sort of error [log] corrections. It appears that Phases 1 and 2 of MD vs ND and phase 5 of ED vs ND appear to obey non normal distribution and hence a log transformation is necessary for the said phases.

6.1 Tests

Now, after observing normality in distribution in almost all of PP phases in all the sessions, we proceed on to carrying a t-test on the difference vector obtained. s

Null Hypothesis: There is no significant difference in the means of respective phases between PP values.

Alternate Hypothesis: There is a significant difference in the means of respective phases between PP values.

Phase1 CD-ND PP t-test:

```
> t.test(diffvectorph1CD,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1CD
t = 1.0833, df = 58, p-value = 0.2831
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.0001140317  0.0003830599
sample estimates:
   mean of x
0.0001345141
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase2 CD-ND PP t-test:

```
> t.test(diffvectorph2CD,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2CD
t = 4.9454, df = 58, p-value = 6.845e-06
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.0004590816 0.0010834422
sample estimates:
   mean of x
0.0007712619
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.

Phase3 CD-ND PP t-test:

```
> t.test(diffvectorph3CD,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3CD
t = 2.5482, df = 58, p-value = 0.0135
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 5.215747e-05 4.342843e-04
sample estimates:
   mean of x
0.0002432209
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.

Phase4 CD-ND PP t-test:

```
> t.test(diffvectorph4CD,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4CD
t = 4.0474, df = 58, p-value = 0.0001553
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.0003336673 0.0009866647
sample estimates:
  mean of x
0.000660166
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.

Phase5 CD-ND PP t-test:

```
> t.test(diffvectorph5CD,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5CD
t = -0.46904, df = 58, p-value = 0.6408
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.0003691535  0.0002289968
sample estimates:
    mean of x
-7.007835e-05
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase1 ED-ND PP t-test:

```
> t.test(diffvectorph1ED,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1ED
t = 1.4742, df = 58, p-value = 0.1458
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -4.505378e-05  2.968431e-04
sample estimates:
   mean of x
0.0001258946
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase2 ED-ND PP t-test:

```
> t.test(diffvectorph2ED,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2ED
t = 4.8208, df = 58, p-value = 1.071e-05
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.0004214213 0.0010198836
sample estimates:
   mean of x
0.0007206524
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.

Phase3 ED-ND PP t-test:

```
> t.test(diffvectorph3ED,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3ED
t = 0.49327, df = 58, p-value = 0.6237
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.0001704823  0.0002819783
sample estimates:
   mean of x
5.574802e-05
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase4 ED-ND PP t-test:

```
> t.test(diffvectorph4ED,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4ED
t = 3.6574, df = 58, p-value = 0.0005508
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.0002334232 0.0007978277
sample estimates:
   mean of x
0.0005156255
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.
Phase5 ED-ND PP t-test:

```
> diffvectorph5EDT = log(diffvectorph5ED-min(diffvectorph5ED)+1)
> t.test(diffvectorph5EDT,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5EDT
t = 25.929, df = 58, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.004077722 0.004760006
sample estimates:
  mean of x
0.004418864
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.
Phase1 MD-ND PP t-test:

```
> diffvectorph1MDT = log(diffvectorph1MD-min(diffvectorph1MD)+1)
> t.test(diffvectorph1MDT,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph1MDT
t = 29.55, df = 51, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.01068228 0.01223957
sample estimates:
 mean of x
0.01146092
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.

Phase2 MD-ND PP t-test:

```
> diffvectorph2MDT = log(diffvectorph2MD-min(diffvectorph2MD)+1)
> t.test(diffvectorph2MDT,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph2MDT
t = 22.889, df = 51, p-value < 2.2e-16
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 0.008991806 0.010720801
sample estimates:
  mean of x
0.009856304
```

we observe that p-value is less than alpha (0.05),hence we reject the null hypothesis, there is **significant difference in the means**.

Phase3 MD-ND PP t-test:

```
> t.test(diffvectorph3MD,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph3MD
t = 0.44165, df = 51, p-value = 0.6606
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.0006426536  0.0010051574
sample estimates:
   mean of x
0.0001812519
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase4 MD-ND PP t-test:

```
> t.test(diffvectorph4MD,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph4MD
t = 1.0239, df = 51, p-value = 0.3107
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.0004813701  0.0014835353
sample estimates:
   mean of x
0.0005010826
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Phase5 MD-ND PP t-test:

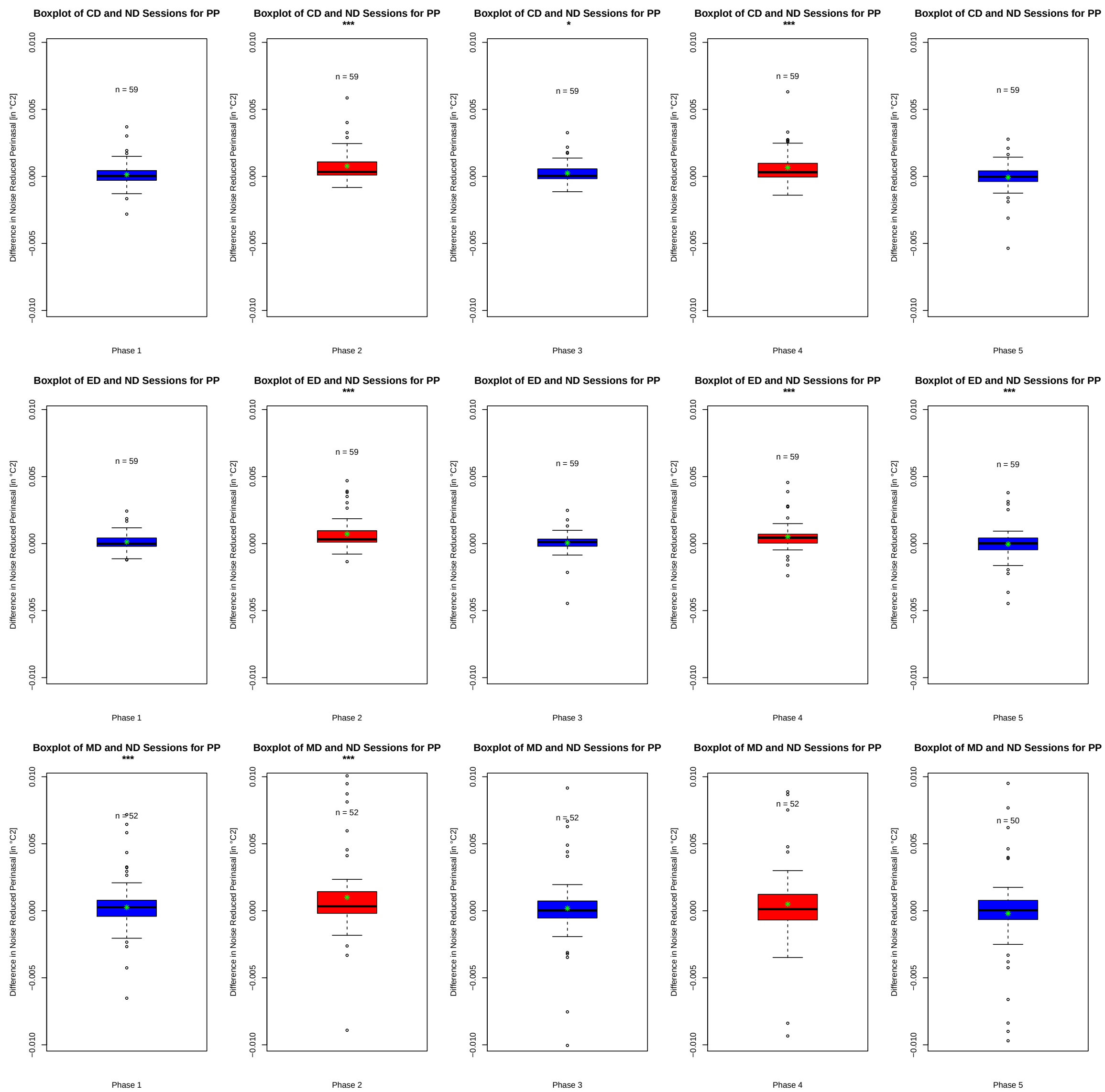
```
> t.test(diffvectorph5MD,conf.level = 0.95)

        One Sample t-test

data:  diffvectorph5MD
t = -0.38965, df = 49, p-value = 0.6985
alternative hypothesis: true mean is not equal to 0
95 percent confidence interval:
 -0.0011920723  0.0008048751
sample estimates:
    mean of x
-0.0001935986
```

we observe that p-value is greater than alpha (0.05),hence we accept the null hypothesis, there is **no significant difference in the means**.

Box Plot of all phases all sessions PP:



7 Conclusions and Interpretations

7.1 Breathing Rate Analysis

7.1.1 Cognitive Drive analysis

After doing paired t test on the adjusted data set following the rules of normal distribution, we have observed **there are no significant differences in the mean Breathing Rates of subjects undergoing cognitive drive session with respect to Normal drive session**.

7.1.2 Emotional Drive Analysis

we have observed **there are no significant differences in the mean Breathing Rates of subjects undergoing Emotional drive session with respect to Normal drive session for phases 1 2 4 and 5**.And phase 3 showed us a significant difference.

7.2 Motoric Drive Analysis

we have observed **there are significant differences in the mean Breathing Rates of subjects undergoing Motoric drive session with respect to Normal drive session for phases 2 4 and 5**.And phase 1 and 3 gave us no significant differences.
So it can be concluded that **Breathing Rate is not really a potential indicator for stress testing** as it is only efficient [as it can be seen] in Motoric drive and significant difference in phase 5 of MD can be attributed for that it can be because of a carryover effect as time slice values are continuous and not discrete in nature.

7.3 Heart Rate Analysis

7.3.1 Cognitive Drive Analysis

we have observed **there are significant differences in the mean Heart Rates of subjects undergoing Cognitive drive session with respect to Normal drive session for phases 2 and 4**.And phase 1,3 and 5 showed us a non significant difference.

7.3.2 Emotional Drive Analysis

we have observed **there are significant differences in the mean Heart Rates of subjects undergoing Emotional drive session with respect to Normal drive session for phases 2,4 and 5**.And phase 1and 3 gave us a non significant difference.

7.3.3 Motoric Drive Analysis

we have observed **there are no significant differences in the mean Heart Rates of subjects undergoing Motoric drive session with respect to Normal drive session for phases 2,4 and 5**
So it can be concluded that *Heart Rate signal set is a really good indicator for stress testing on subjects undergoing Emotional and Cognitive Drive sessions* with respect to normal drive session and **did not prove effective on Motoric drive analysis.**

7.4 Palm EDA Analysis

Palm EDA signal set gave us really poor results on almost all of the sessions [motoric,cognitive,emotional] with respect to Normal drive sessions, except for the fact that it gave us significant difference in means on phases 1 and 2 of Motoric drive.

7.5 Perinasal perspiration Analysis

7.5.1 Cognitive Drive Analysis

we have observed **there are significant differences in the mean Perinasal Perspiration rates of subjects undergoing Cognitive drive session with respect to Normal drive session for phases 2,3 and 4**.And phase 1 and 5 showed us a non significant difference.

7.5.2 Emotional Drive Session

we have observed **there are significant differences in the mean Perinasal Perspiration rates of subjects undergoing Emotional drive session with respect to Normal drive session for phases 2 and 4**.And phase 1,3 and 5 showed us a non significant difference.

7.5.3 Motoric Drive Session

we have observed **there are significant differences in the mean Perinasal Perspiration rates of subjects undergoing Motoric drive session with respect to Normal drive session for phases 1,2,4 and 5**.And phase 3 showed us a non significant difference.

Final Observation: *Perinasal Perspiration and Heart Rate can be considered as potential indicators of stress being significant on phases 2 and 4.*

Significance Level Notation on Boxplots:
p-value >0.05 then No Stars
p-value between 0.01-0.05 then *
p-value between 0.001-0.01 then **
p-value <0.001 then *