SA1 TIME SERIES Q30

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Contents

READING THE DATA

Import

```r
print(head(server_data))
```

```
##   Server Server.Type Security.Protocol     Time Response.Time
## 1      1       Linux               SSL Baseline       93.8812
## 2      2     Windows               TLS Baseline      160.1052
## 3      3     Windows               SSL Baseline      134.2862
## 4      4       Linux               TLS Baseline      109.5037
## 5      5     Windows               SSL Baseline      132.9666
## 6      6       Linux               SSL Baseline      110.9772
```

1. Check Assumptions

Normality: Shapiro-Wilk

```r
unique_servers <- unique(server_data$Server)

print(unique_servers)
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
```

With Unique Value in Server namely 1-20, we will get its normality to figure if server response times should follow a normal distribution within each group.

```r
kable(normality_results_df)
```

Server	p_value
1	0e+00
2	0e+00
3	1e-07
4	1e-07
5	0e+00
6	1e-07
7	0e+00
8	0e+00
9	0e+00
10	1e-07
11	0e+00
12	0e+00
13	1e-07
14	0e+00
15	0e+00
16	0e+00
17	1e-07
18	1e-07
19	0e+00
20	0e+00

Sphericity: w/correction of Greenhouse-Geisser

```r
print(sphericity_test)
```

```
## $ANOVA
##        Effect DFn DFd         SSn       SSd          F            p p<.05
## 1 (Intercept)   1  19 900511.3016 22988.055 744.287189 1.057845e-16     *
## 2        Time   2  38    530.9533  1501.923   6.716799 3.178316e-03     *
##          ges
## 1 0.97352439
## 2 0.02122037
```

```
##
## $`Mauchly's Test for Sphericity`
##   Effect         W           p p<.05
## 2   Time 0.5592526 0.005351456     *
##
## $`Sphericity Corrections`
##   Effect       GGe       p[GG] p[GG]<.05       HFe       p[HF] p[HF]<.05
## 2   Time 0.6940842 0.009114592         * 0.7314221 0.008008614         *
```

With our sphericity_test concluded <.05, we need to perform Greenhouse-Geisser Results

```r
print(sphericity_corrections)
```

```
##   Effect       GGe       p[GG] p[GG]<.05       HFe       p[HF] p[HF]<.05
## 2   Time 0.6940842 0.009114592         * 0.7314221 0.008008614         *
```

```r
cat("Greenhouse-Geisser (GG) corrected p-value for Time:", greenhouse_geisser_p_value, "\n")
```

```
## Greenhouse-Geisser (GG) corrected p-value for Time: 0.009114592
```

```r
server_data$Server <- as.factor(server_data$Server)
levene_test_result <- leveneTest(Response.Time ~ Server, data = server_data)
print(levene_test_result)
```

```
## Levene's Test for Homogeneity of Variance (center = median)
##         Df F value    Pr(>F)
## group   19  6.4712 2.862e-16 ***
##       1180
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Independence

```r
if (nrow(overlapping_servers) > 0) {
  print("The following servers have overlapping response times across different time points:")
  print(overlapping_servers)
} else {
  print("All servers are independent across time points.")
}
```

```
## [1] "All servers are independent across time points."
```

Findings for Check Assumptions

Since there is a **statistically significant difference** between the means across the time groups and the **Greenhouse-Geisser corrected p-value**, we can move further with ANOVA. Furthermore, the **Greenhouse-Geisser correction** is justified since the results of **Mauchly's Test for Sphericity** indicate that the assumption of sphericity is violated. The requirement for corrections for valid ANOVA findings is further supported by the **substantial results of Levene's Test**, which also reveal that the assumption of homogeneity of variances is broken.

2. Conduct the Two-Way Mixed Model ANOVA

Main Effect

Including: Two-way mixed model ANOVA

- **Between-Subjects Factor 1: Server Type**
  - Linux vs. Windows
- **Between-Subjects Factor 2: Security Protocol**
  - TLS (Transport Layer Security) vs. SSL (Secure Sockets Layer)
- **Within-Subjects Factor: Time**
  - Baseline (Time 1), After 1 Month (Time 2), After 2 Months (Time 3)
- **Dependent Variable: Server Response Time** (measured in milliseconds)

Here, since our sphericity is violated this part of my code performs the ANOVA with Greenhouse-Geisser correction

```r
summary(anova_results)
```

```
##                                       Df Sum Sq Mean Sq  F value   Pr(>F)    
## Server.Type                            1 335713  335713 4179.213  < 2e-16 ***
## Security.Protocol                      1   5355    5355   66.660 8.17e-16 ***
## Time                                   2  10619    5310   66.097  < 2e-16 ***
## Server.Type:Security.Protocol          1  31263   31263  389.185  < 2e-16 ***
## Server.Type:Time                       2  18702    9351  116.409  < 2e-16 ***
## Security.Protocol:Time                 2   1731     866   10.777 2.30e-05 ***
## Server.Type:Security.Protocol:Time     2   1604     802    9.982 5.02e-05 ***
## Residuals                           1188  95431      80                      
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Findings:

The results indicate significant main effects for Server Type, Security Protocol, and Time on server response times, suggesting that each of these influences the performance of the servers. The significant interaction effect between Server Type and Security Protocol implies that the impact of the server type on response times varies depending on the security protocol used.

3. Interaction Effect

- **Server Type, Security Protocol, and Time Main Effects**: The study shows that each of the three variables has a significant main effect, suggesting that **Server Type**, **Security Protocol**, and **Time** all have an independent impact on server response times.
- **Interaction Effect between Server Type and Security Protocol**: The interaction effect between **Server Type** and **Security Protocol** is significant, with the security protocol determining the impact on response times. For example, the performance of *Linux servers* may differ significantly from *Windows servers* based on the usage of *TLS* or *SSL*.
- **Interaction Effect between Server Type and Time**: This relationship shows that the impact of **Server Type** on response times changes over the various **Time** periods evaluated. This implies that server performance characteristics may change when the server is used over time, resulting in varying outcomes at each step.
- **Interaction Effect between Security Protocol and Time**: **Security Protocol** success rates may vary over time due to interaction effects, affecting performance relative to server response times. This necessitates constant monitoring for optimal server management.

POST-HOC

Post-Hoc

```
print(pairwise_results)
```

```
##  contrast                                    estimate   SE   df t.ratio p.value
##  Linux SSL 1 Month - Windows SSL 1 Month       -16.51 1.34 1188 -12.277  <.0001
##  Linux SSL 1 Month - Linux TLS 1 Month           5.92 1.26 1188   4.714  0.0002
##  Linux SSL 1 Month - Windows TLS 1 Month       -30.86 1.42 1188 -21.779  <.0001
##  Linux SSL 1 Month - Linux SSL 2 Months         -2.90 1.42 1188  -2.049  0.6592
##  Linux SSL 1 Month - Windows SSL 2 Months      -19.40 1.34 1188 -14.430  <.0001
##  Linux SSL 1 Month - Linux TLS 2 Months          2.06 1.26 1188   1.640  0.8942
##  Linux SSL 1 Month - Windows TLS 2 Months      -41.51 1.42 1188 -29.295  <.0001
##  Linux SSL 1 Month - Linux SSL Baseline         10.80 1.42 1188   7.624  <.0001
##  Linux SSL 1 Month - Windows SSL Baseline      -25.98 1.34 1188 -19.327  <.0001
##  Linux SSL 1 Month - Linux TLS Baseline         16.24 1.26 1188  12.930  <.0001
##  Linux SSL 1 Month - Windows TLS Baseline      -36.06 1.42 1188 -25.443  <.0001
##  Windows SSL 1 Month - Linux TLS 1 Month        22.43 1.17 1188  19.112  <.0001
##  Windows SSL 1 Month - Windows TLS 1 Month     -14.36 1.34 1188 -10.680  <.0001
##  Windows SSL 1 Month - Linux SSL 2 Months       13.60 1.34 1188  10.117  <.0001
##  Windows SSL 1 Month - Windows SSL 2 Months     -2.89 1.27 1188  -2.283  0.4892
##  Windows SSL 1 Month - Linux TLS 2 Months       18.57 1.17 1188  15.820  <.0001
##  Windows SSL 1 Month - Windows TLS 2 Months    -25.01 1.34 1188 -18.602  <.0001
##  Windows SSL 1 Month - Linux SSL Baseline       27.31 1.34 1188  20.313  <.0001
##  Windows SSL 1 Month - Windows SSL Baseline     -9.48 1.27 1188  -7.477  <.0001
##  Windows SSL 1 Month - Linux TLS Baseline       32.75 1.17 1188  27.906  <.0001
##  Windows SSL 1 Month - Windows TLS Baseline    -19.55 1.34 1188 -14.542  <.0001
##  Linux TLS 1 Month - Windows TLS 1 Month       -36.79 1.26 1188 -29.284  <.0001
##  Linux TLS 1 Month - Linux SSL 2 Months         -8.83 1.26 1188  -7.026  <.0001
##  Linux TLS 1 Month - Windows SSL 2 Months      -25.32 1.17 1188 -21.578  <.0001
##  Linux TLS 1 Month - Linux TLS 2 Months         -3.86 1.07 1188  -3.606  0.0169
##  Linux TLS 1 Month - Windows TLS 2 Months      -47.44 1.26 1188 -37.763  <.0001
##  Linux TLS 1 Month - Linux SSL Baseline          4.88 1.26 1188   3.886  0.0060
##  Linux TLS 1 Month - Windows SSL Baseline      -31.90 1.17 1188 -27.188  <.0001
##  Linux TLS 1 Month - Linux TLS Baseline         10.32 1.07 1188   9.633  <.0001
##  Linux TLS 1 Month - Windows TLS Baseline      -41.98 1.26 1188 -33.418  <.0001
##  Windows TLS 1 Month - Linux SSL 2 Months       27.96 1.42 1188  19.730  <.0001
##  Windows TLS 1 Month - Windows SSL 2 Months     11.46 1.34 1188   8.527  <.0001
##  Windows TLS 1 Month - Linux TLS 2 Months       32.92 1.26 1188  26.210  <.0001
##  Windows TLS 1 Month - Windows TLS 2 Months    -10.65 1.42 1188  -7.516  <.0001
##  Windows TLS 1 Month - Linux SSL Baseline       41.67 1.42 1188  29.403  <.0001
##  Windows TLS 1 Month - Windows SSL Baseline      4.88 1.34 1188   3.631  0.0155
##  Windows TLS 1 Month - Linux TLS Baseline       47.11 1.26 1188  37.500  <.0001
##  Windows TLS 1 Month - Windows TLS Baseline     -5.19 1.42 1188  -3.664  0.0138
##  Linux SSL 2 Months - Windows SSL 2 Months     -16.50 1.34 1188 -12.270  <.0001
##  Linux SSL 2 Months - Linux TLS 2 Months         4.96 1.26 1188   3.951  0.0047
##  Linux SSL 2 Months - Windows TLS 2 Months     -38.61 1.42 1188 -27.246  <.0001
##  Linux SSL 2 Months - Linux SSL Baseline        13.71 1.42 1188   9.673  <.0001
##  Linux SSL 2 Months - Windows SSL Baseline     -23.08 1.34 1188 -17.167  <.0001
##  Linux SSL 2 Months - Linux TLS Baseline        19.15 1.26 1188  15.242  <.0001
##  Linux SSL 2 Months - Windows TLS Baseline     -33.15 1.42 1188 -23.393  <.0001
##  Windows SSL 2 Months - Linux TLS 2 Months      21.46 1.17 1188  18.287  <.0001
```

```
##  Windows SSL 2 Months - Windows TLS 2 Months   -22.11 1.34 1188 -16.449  <.0001
##  Windows SSL 2 Months - Linux SSL Baseline      30.20 1.34 1188  22.466  <.0001
##  Windows SSL 2 Months - Windows SSL Baseline    -6.58 1.27 1188  -5.194  <.0001
##  Windows SSL 2 Months - Linux TLS Baseline      35.64 1.17 1188  30.372  <.0001
##  Windows SSL 2 Months - Windows TLS Baseline   -16.66 1.34 1188 -12.389  <.0001
##  Linux TLS 2 Months - Windows TLS 2 Months     -43.57 1.26 1188 -34.689  <.0001
##  Linux TLS 2 Months - Linux SSL Baseline         8.74 1.26 1188   6.961  <.0001
##  Linux TLS 2 Months - Windows SSL Baseline     -28.04 1.17 1188 -23.896  <.0001
##  Linux TLS 2 Months - Linux TLS Baseline        14.18 1.07 1188  13.239  <.0001
##  Linux TLS 2 Months - Windows TLS Baseline     -38.11 1.26 1188 -30.343  <.0001
##  Windows TLS 2 Months - Linux SSL Baseline      52.32 1.42 1188  36.918  <.0001
##  Windows TLS 2 Months - Windows SSL Baseline    15.53 1.34 1188  11.553  <.0001
##  Windows TLS 2 Months - Linux TLS Baseline      57.76 1.26 1188  45.979  <.0001
##  Windows TLS 2 Months - Windows TLS Baseline     5.46 1.42 1188   3.852  0.0069
##  Linux SSL Baseline - Windows SSL Baseline     -36.79 1.34 1188 -27.362  <.0001
##  Linux SSL Baseline - Linux TLS Baseline         5.44 1.26 1188   4.329  0.0010
##  Linux SSL Baseline - Windows TLS Baseline     -46.86 1.42 1188 -33.066  <.0001
##  Windows SSL Baseline - Linux TLS Baseline      42.22 1.17 1188  35.982  <.0001
##  Windows SSL Baseline - Windows TLS Baseline   -10.07 1.34 1188  -7.492  <.0001
##  Linux TLS Baseline - Windows TLS Baseline     -52.30 1.26 1188 -41.633  <.0001
##
## P value adjustment: tukey method for comparing a family of 12 estimates
```

Findings:

- **Tukey's HSD analysis** reveals significant variations in response times across servers and security protocols.
- A one-month **Linux SSL setup** responds faster than **Windows SSL** and **Linux TLS** setups, with **p-values smaller than 0.0001**.
- However, some comparisons, such as **Linux SSL at one month** versus **Linux SSL at two months**, do not show statistically significant differences, suggesting that not all transitions across different configurations are statistically significant.

RESULTS

The results of the analysis indicate significant main effects for Server Type, Security Protocol, and Time on server response times, suggesting that each factor independently influences server performance. The interaction effect between Server Type and Security Protocol was significant, meaning the impact of server type on response times varied based on the security protocol used. Additionally, the interaction between Server Type and Time revealed that server performance changed over time, depending on the type of server. A significant interaction between Security Protocol and Time was also found, showing that security protocol effectiveness fluctuated across time periods. Post-hoc analyses further confirmed these significant differences across various combinations of server types, protocols, and time points.