MIE237: Final Report

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Introduction:

Research Question: Does communicating information during gaming result in worse performance?

In any team-based game from sports to video games, effective communication is essential to the team's success. Even a slight lack of communication can result in the team not playing at its best level[1]. In Player vs Player (PvP) multiplayer video games, communicating information to the team is a crucial aspect for winning matches. However, it is equally important to focus on the actions individual players must perform using a mouse and keyboard, such as aiming their weapon accurately in the First-Person Shooter (FPS) genre of PvP games [2]. Our research question aims to address whether verbal communication has an impact on a player's individual performance.

Our hypothesis: Verbal communication during First-Person Shooters leads to an increase in response time, and a decrease in accuracy.

Similar studies have been conducted when it comes to how reaction time is impacted by conversations. One such example is how reaction time when driving up to a changing stop light increases when conversations with the driver are occurring, in comparison to reaction time without any conversation [3]. This experiment aims to see if this observation is applicable in the context of first-person shooting games.

To evaluate the hypothesis, the team will conduct experiments measuring participants' reaction time and accuracy in a target clicking exercise under varying levels of communication-related distraction. After collecting data from participants, conclusions will be made using various data analysis techniques to evaluate the research question. The goal is to determine whether there is any significant difference between the mean reaction time and accuracy of varying distraction levels.

Methods:

Variables/Context

This experiment will be conducted on participants of ages 18-24, in addition to having a minimum of 50 hours of experience in competitive multiplayer video games to ensure that there is no confounding variable of prior experience. There is no restriction on the participant's gender or ethnicity. The experiment will be conducted on these participants due to the fact that this age range has been known to contain the majority of first person shooter players [4].

The experiment will be conducted using the target clicking game **AimBooster** as the apparatus, where the participant must click on oncoming targets. The exact set of game settings applied can be found in Appendix A. The game consists of a series of orange circles that appear on the participant's screen that when clicked, disappear and prompt a new target to appear. Additionally, the target slowly fades away over time, automatically disappearing if the participant fails to click on it within 1.3 seconds of its appearance. Each game has a duration of 1 minute. The figure below displays how the Aimbooster game functions.

Figure 1: A screenshot of *AimBooster.com*

The participant's accuracy and mean reaction time will be recorded from the experiment. **Accuracy** is defined as the total number of clicks on a target divided by the total number of

clicks. **Mean reaction time** is defined as the mean amount of time the participant takes before clicking a target after it has appeared.

Since competitive PvP games often require quickly and accurately hitting opposing players as soon as they appear on-screen, an individual's performance in games can be determined through the mean reaction time and accuracy. Thus, the experiment's dependent variables will be the mean reaction time and accuracy.

For this experiment, the independent variable is a qualitative variable denoted by “Distraction Type”, which consists of varying environmental conditions during each round of the trial. A distraction consists of a cognitive task, involving listening and/or verbal communication. There are three defined distraction levels: **no** distraction, **minor** distraction, and **major** distraction. The no distraction level consists of participants playing the game with no external influence. The minor distraction level involves participants playing the game while having to listen to a script. The major distraction level involves participants playing the game while answering basic questions.

Procedure

The team will conduct **paired observations** for the experiment, in which each participant is tasked with completing a single round for each test type (no distraction, minor distraction, major distraction). Thus, each trial consists of a participant completing 3 different rounds. In order to ensure the participants fit within our user group, these screening questions were asked prior to the experiment:

Screening Questions

1. What is your age?
2. How many hours total do you have in competitive video games?

After ensuring that all participants meet the criteria defined previously, the researcher will then explain the rules for how the test will proceed. The participant will first be given the opportunity

to practice the game by playing 1-3 rounds to familiarize themselves with the game's environment and settings. After the practice rounds, the participant will then start the trial.

The trial starts with the no distraction round, where the participant will play the game without any distractions. Following the first round, the participant will proceed to play the second round, where they will play the game as a researcher reads them a one minute monologue from a standardized script. After the completion of the second round, the participant will then undergo the final round, in which they will play the game while answering a series of short-answer questions from a standardized list, asked by the researcher. The participant is encouraged to answer the questions accurately to best simulate an exchange of information. The trial will be concluded once this round is completed.

There is potential bias in the data due to differences in hardware or the configurations used by the participants. Since participants were tested online and were allowed to use their own personal PC setup, differences in hardware could result in some participants receiving better results than others. Another possible source of bias could result from the possibility of participants performing better in later rounds compared to earlier rounds. All participants were asked to conduct the rounds in the same order, resulting in the possibility for performances to improve as participants become more acclimated to the website. However, the practice rounds provided to the participant aims to minimize this bias.

Initialization of Dataset:

The team measured results for all 3 distraction types from 24 different individuals. These results were organized into a Google Sheet, then compiled into 2 separate CSV files for mean reaction time and accuracy. See Appendix C for the datasets.

Analyses:

To determine whether there is any significant difference between the distraction types, the team performed an analysis on the differences of the **means** between the three groups of data. This experiment will use a **significance level of $\alpha = 0.05$**. Before performing any statistical tests, the

data was evaluated for the normality and homogeneous variance assumptions. For the homogeneity assumption, the residuals were plotted against the fitted mean, in addition to the Levene test. For the normality assumption, the data was plotted on a quantile-quantile plot, in addition to the Shapiro-Wilk test.

To determine relevant descriptive statistics, boxplots were created for each type of distraction to visualize the differences between the medians and distributions of each distraction level. Mean plots were constructed to show the means of each distraction level, and their distributions.

Following this, inferential statistics were determined using a one-way analysis of variance, or ANOVA, which was performed on both the reaction time and accuracy datasets. The corresponding null and alternative hypothesis are shown below. (0 = no distraction, 1 = minor distraction, 2 = major distraction). Based on the p-values of these tests, the team would be able to determine whether there is a significant difference between all three means.

H_0: $\mu_0 = \mu_1 = \mu_2$
$\Rightarrow$ There are no significant differences between the mean reaction time/accuracy across different distraction types

H_1: $\mu_0 \neq \mu_1 \neq \mu_2$
$\Rightarrow$ There may be significant differences between the mean reaction time/accuracy across different distraction types

To further investigate the relationship between each distraction, a series of pairwise T-tests were conducted on each of the possible pairs that can be formed between the **no** distraction, **minor** distraction, and **major** distraction groups. The null and alternative hypotheses for each pair within the set are shown below.

	No - Minor distraction	No - Major distraction	Minor - Major distraction

Reaction Time	H_0: $\mu_0 = \mu_1$ H_1: $\mu_0 < \mu_1$	H_0: $\mu_0 = \mu_1$ H_1: $\mu_0 < \mu_1$	H_0: $\mu_0 = \mu_1$ H_1: $\mu_0 < \mu_1$
Accuracy	H_0: $\mu_0 = \mu_1$ H_1: $\mu_0 > \mu_1$	H_0: $\mu_0 = \mu_1$ H_1: $\mu_0 > \mu_1$	H_0: $\mu_0 = \mu_1$ H_1: $\mu_0 > \mu_1$

Table 1. Pairwise T-test hypotheses

Results:

Assumptions

The results of the evaluation of the normality and homogeneity assumptions demonstrated that the data was sufficient for ANOVA and pairwise T-tests. For the homogeneity assumption, the residuals vs fitted values plots can be observed below:

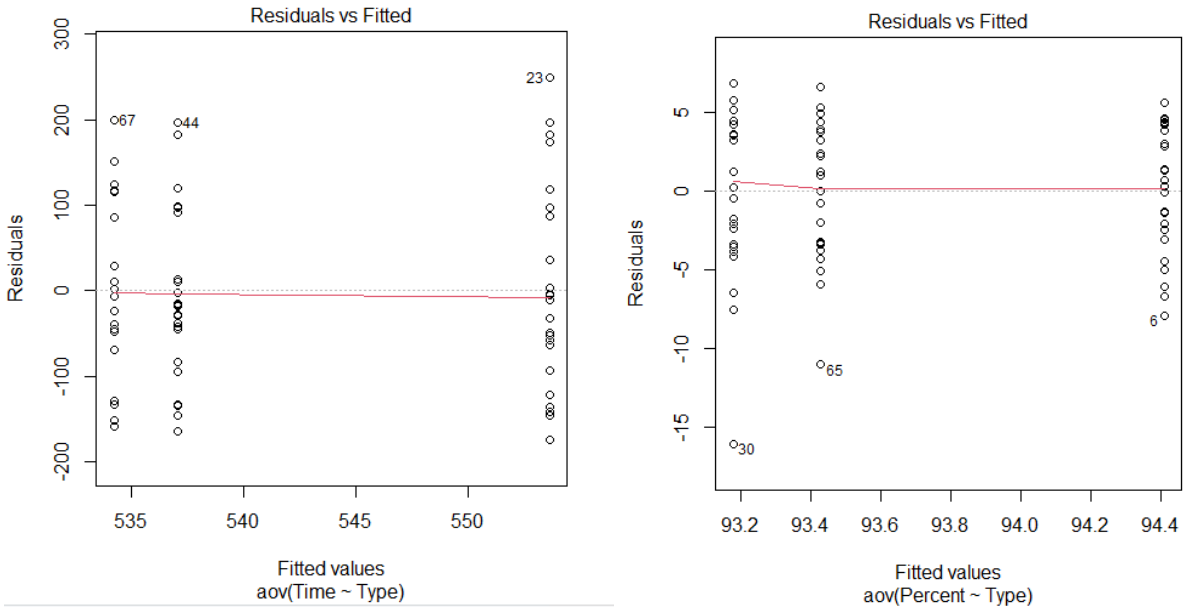

Figure 2. Residual vs. Fitted Value Plots (mean reaction time - left, accuracy - right)

The residuals are distributed around 0, and there are no extreme outliers. Additionally, the Levene tests return p-values that are greater than the significance level of 0.05, indicating that the homogeneity assumptions hold for both the reaction time and accuracy datasets.

```
Levene's Test for Homogeneity of Variance (center = median)
      Df F value Pr(>F)
group  2  0.2805 0.7563
      69
```

Figure 3. Levene's test for accuracy

```
Levene's Test for Homogeneity of Variance (center = median)
      Df F value Pr(>F)
group  2  0.7215 0.4897
      69
```

Figure 4. Levene's test for mean reaction time

For the normality assumption, the Q-Q plot and the Shapiro-Wilks test indicate that the datasets are **not** normally distributed. However, the ANOVA test is robust to the normality assumption, indicating that the probability of a type I error does not significantly increase with the lack of a normally distributed sample [5]. Additionally, since our dataset has a sample size of 24 for each distraction type, the pairwise T-tests will yield a reasonable result by the Central Limit Theorem [6].

Descriptive Statistics

In order to compare the means for each measurement variable, box plots were constructed to compare the medians for mean reaction time and accuracy for each distraction intensity. The box plots in Figure 2 visually indicate that there is no significant difference between the medians and interquartile range of each plot.

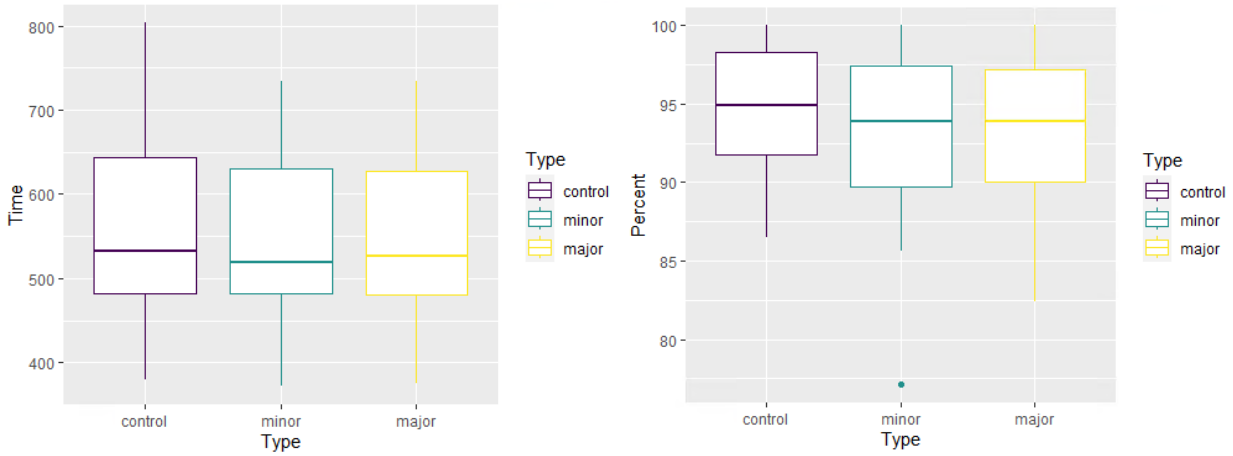

Figure 5. Box-plot for each distraction type (mean reaction time - left, accuracy - right)

The team also constructed mean plots to compare the mean distribution of accuracy and mean reaction time with respect to different distraction types. The mean plots are shown below:

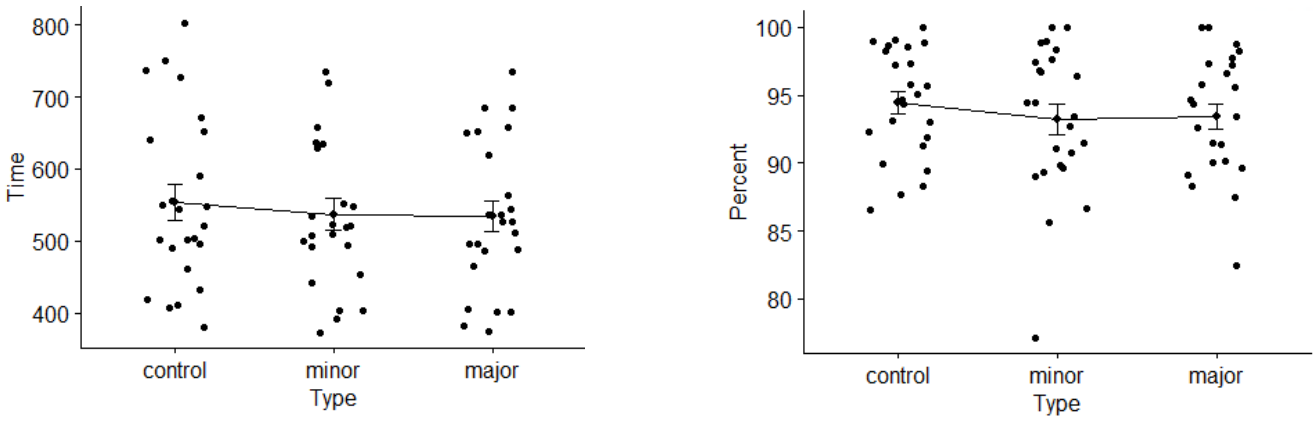

Figure 6. Mean-plot for each distraction type (mean reaction time - left, accuracy - Right)

The descriptive statistics of the dataset indicates that there is a similar distribution between all 3 distraction groups, with minimal differences between their means and medians. See Appendix D for the exact values of descriptive statistics.

Inferential Statistics

The ANOVA test yielded the following results shown in the table below. For both mean reaction time and accuracy, the p-value was significantly higher than the level of significance (0.05). This indicates that there is no significant evidence to disprove the null hypothesis, and the result is that there was failure to reject the null hypothesis.

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Type	2	5294	2647	0.219	0.8040
Residuals	69	834203	12090		

Table 2. ANOVA table for mean reaction time

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Type	2	20.3	10.13	0.456	0.636
Residuals	69	1534.1	22.23		

Table 3. ANOVA table for accuracy

The p-values for each of the pairs involved in the pairwise T-tests can be observed below. For accuracy, there is a significant relationship between no distraction and minor distraction, and a potential significant relationship between no distraction and major distraction. There is no significant relationship between the minor and major distraction.

p-value	No - Minor	No - Major	Minor - Major
Mean Reaction Time	0.9596	0.9670	0.3414
Accuracy	0.02504	0.07691	0.3909

Table 4. Pairwise T-test p-values for accuracy and mean reaction time with respect to the distraction types

Since extremely high p-values were observed for the mean reaction time pairs, the team decided to invert the one-sided alternative hypothesis (e.g. $\mu_0 < \mu_1$ changed to $\mu_0 > \mu_1$) to determine whether the mean reaction time decreased as more severe distractions were applied. The resulting p-values for these hypotheses can be observed below.

p-value	No - Minor	No - Major	Minor - Major
Mean Reaction Time	0.04042	0.03298	0.6586

Table 5. Revised pairwise T-test p-values for mean reaction time, with a modified alternative hypothesis

From these new p-values, it seems that there is indeed a significant relationship for pairs involving no distraction and any other distraction type, while the minor - major distraction pair relationship was not statistically significant.

Conclusion:

Based on the results of the analysis, there are several conclusions that can be drawn from this experiment. First, there is evidence that a player's **reaction time** actually **decreases** with the introduction of any distraction. There is no indication that the severity of the distraction (minor/major) further decreases reaction time. This can be interpreted by the observation that players might be less focused on the primary task of clicking, which leads to more rushed actions.

Next, there is evidence that a player's **accuracy decreases** with the introduction of a minor distraction, and possibly a major distraction. Again, there is no indication that the severity of the distraction (minor/major) further decreases accuracy. This can be interpreted as players settling for simply clicking anywhere on the target as they focus on the secondary task of communication.

This experiment had several limitations. First, the normality assumption was not explicitly met, as the sample data was not normally distributed. This can be addressed with the addition of more trials, increasing our sample size. An increase in sample size also decreases the standard error, with less variation between sample statistics. Additionally, there was a bias regarding participants doing the trials on different hardware, which further increases variability. This can be resolved by having participants perform the trial on identical setups. Finally, there is potential bias with participants performing trials in succession, which may make these participants more acclimated to the apparatus. Participants can be given further time to prepare and familiarize themselves with the website, or the participant group can consist of people who have prior experience with the website.

Thus, the answer to the research question is not a binary answer; different aspects of a player's overall performance may change with the presence of a distraction. The only conclusion that can be made is that the **presence of any external distraction has an effect on a player's performance.**

References:

[1] "How Effective Communication Relates to Performance in Teams," *Applied Social Psychology ASP RSS*, 25-Feb-2018. [Online]. Available: https://sites.psu.edu/aspsy/2018/02/25/how-effective-communication-relates-to-performance-in-teams/. [Accessed: 08-Apr-2023].

[2] A. Leavitt, B. C. Keegan, and J. Clark, "Ping to win?: Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems," *ACM Digital Library*, 07-May-2016. [Online]. Available: https://dl.acm.org/doi/abs/10.1145/2858036.2858132. [Accessed: 08-Apr-2023].

[3] S. M. Bowyer, L. Hsieh, J. E. Moran, R. A. Young, A. Manoharan, C.-cheng J. Liao, K. Malladi, Y.-J. Yu, Y.-R. Chiang, and N. Tepley, "Conversation effects on neural mechanisms underlying reaction time to visual events while viewing a driving scene using Meg," *Brain research*, 28-Jan-2009. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2741688/. [Accessed: 08-Apr-2023].

[4] J. Clement, "Global shooter video gamers by age 2018," *Statista*, 24-Jun-2021. [Online]. Available: https://www.statista.com/statistics/1129298/age-distribution-shooter-video-gamers/. [Accessed: 09-Apr-2023].

[5] M. J. Blanca , R. Alarcón, J. Arnau, R. Bono, and R. Bandayan, "Non-normal data: Is anova still a valid option?," *Psicothema*, Nov-2017. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/29048317/. [Accessed: 09-Apr-2023].

[6] D. Long, "The t-test," *CMU School of Computer Science*, 06-Nov-2006. [Online]. Available: https://www.cs.cmu.edu/afs/cs/project/jair/pub/volume20/long03a-html/node64.html#:~:text=The%20t%2Dtest%20is%20a%20more%20conservative%20version%20of%20the,the%20distribution%20that%20this%20creates. [Accessed: 09-Apr-2023].

Appendices:

Appendix A. AimBooster Settings

#------------------#
TARGET BEHAVIOR
#------------------#
target_size: 70
time_per_target: 1.3
target_speed: 0
constant_target_size: yes
misclick_kills_nearest: no

#----------#
SPAWNING
#----------#
targets_per_sec: 3.1
targets_per_sec_increase_per_min: 0
instant_respawn: yes
spawn_group_size: 1
spawn_in_center: no
randomized_spawntime: no
max_dist_from_previous: -1

#---------#
LIVES
#---------#
lives: 3
misclick_loses_life: no
miss_target_loses_life: no
losing_life_clears_screen: no
time_limit: 60

```
#--------#
#  GRID  #
#--------#
#  note: set these to 0 to
#  enable autoresize
grid_width: 600
grid_height: 420

#---------------#
#  AUTOBALANCE  #
#---------------#
#  note: you can set this to 'nothing',
#  targets_per_sec', 'target_size', or
#  'time_per_target'
autobalance: nothing
autobalance_accuracy: 95%

#------------#
#  GIMMICKS  #
#------------#
invisible_cursor: no
no_need_to_click: no
target_hp: 1
win_if_screen_cleared: no

#-----------------#
#  SMALL DETAILS  #
#-----------------#
allow_overlap: yes
show_reaction_time: no
```

show_timer: yes
target_fade_out_effect: on
losing_life_animation: on
show_target_ghosts: yes
absolute_target_speed: no
target_speed_randomness: 30%
horizontal_movement: 50%
rng_seed: -1

Appendix B. Distractions

Minor Distraction Script:
Hey there, let me tell you about two of my favorite breakfast treats - pancakes and waffles!

First, let's talk about pancakes. There's something so comforting about biting into a fluffy stack of pancakes, drenched in maple syrup and melted butter. The warm, sweet aroma fills your nose and your taste buds come alive with each bite. Whether you like them plain or loaded with toppings like berries or chocolate chips, pancakes are a classic breakfast staple that always hit the spot.

But let's not forget about their counterpart - the waffle. Unlike pancakes, waffles have those signature grid lines that hold in all the delicious toppings. And let me tell you, there's nothing quite like biting into a crispy, golden waffle topped with whipped cream and fresh fruit. The combination of textures and flavors is pure bliss.

One of the great things about pancakes and waffles is that they're so versatile. You can make them sweet or savory, depending on your mood and taste preferences. For example, you can add savory ingredients like cheese and herbs to your pancake batter to make a delicious breakfast option that's a bit different from the usual sweet pancakes. And with waffles, you can top them with chicken and gravy for a hearty Southern-style breakfast or add bacon and eggs for a classic brunch favorite.

So, whether you're team pancake or team waffle, both of these breakfast delights are sure to satisfy your cravings. So go ahead, indulge a little and enjoy every last bite!

Major Distraction Questions:

1. 9+10
2. What color is the web page background
3. What color are the targets?
4. 98/2
5. How much time is left?
6. What is your accuracy?
7. How many targets have you hit?
8. 15 * 3
9. How many lives do you have left?
10. What time is it?
11. 84 - 26
12. What day of the week is it today?
13. What is my name?
14. What school do you go to?
15. 21/7
16. 0/72
17. How was the weather today?
18. How many sides does a triangle have?
19. sqrt(9)
20. 2^4
21. What direction does the sun rise from?
22. How many seconds in an hour?
23. How many days in a year?
24. Favorite letter?
25. 3-1
26. What is H2O?
27. Name an orange coloured fruit?

28. 5*5
29. How many letters in the alphabet?
30. Pancakes or waffles?

Appendix C. Datasets

Full Dataset

		Prelim Questions		Testing (Control)			Testing (Minor Distraction)			Testing (Major Distraction)		
Participant #	Online?	Age?	Total hours?	Avg. Reaction Time (ms)	Accuracy	Precision	Avg. Reaction Time	Accuracy	Precision	Avg. Reaction Time	Accuracy	Precision
1	TRUE	19	500	549.1	98.2	11.9	550.7	100	10.7	495.4	95.8	20.3
2	TRUE	19	500	504.4	95.1	15.7	494.5	90.8	16.8	510.3	98.3	13.9
3	TRUE	19	500	407.5	93.1	16.9	391.2	89.8	20.3	381.7	89.1	22.5
4	TRUE	18	500	431.2	91.3	18.0	402.1	89.6	20.5	375.0	90.1	22.7
5	TRUE	19	500	379.1	91.9	18.9	371.8	89.3	18.9	400.6	87.5	21.1
6	TRUE	19	500	418.0	86.5	21.3	442.6	77.1	23.8	404.6	88.3	22.1
7	TRUE	19	500	411.3	87.7	21.4	404.0	86.7	19.3	401.2	91.4	18.0
8	TRUE	19	430	495.5	88.3	29.6	454.0	91.4	19.5	464.3	92.6	19.5
9	TRUE	19	792	543.2	94.7	17.2	518.7	92.7	18.2	495.4	94.4	17.1
10	TRUE	19	981	556.3	97.2	18.2	547.6	96.4	18.2	563.7	97.2	14.2
11	TRUE	19	230	520.6	95.7	18.2	498.7	94.4	16.9	488.5	89.6	24.6
12	TRUE	20	1000	489.7	99.0	24.6	508.9	98.3	15.5	485.5	97.3	14.9
13	TRUE	20	500	460.3	97.4	14.2	520.1	93.4	16.4	527.1	96.6	14.5
14	TRUE	23	50	727.3	94.3	15.2	636.2	96.8	15.2	649.6	94.6	25.6
15	TRUE	22	50	640.6	98.9	12.9	634.8	98.9	15.8	685.7	100	14.9
16	TRUE	19	500	672.1	98.8	31.3	628	98.9	12.8	651.4	100	8.2
17	TRUE	19	700	500.7	89.9	19.7	491.5	89.0	29.5	527.0	82.4	25.2
18	TRUE	19	200	736.7	92.3	38.9	719.2	97.6	20.3	620.0	91.4	42.6
19	TRUE	19	500	750.1	98.7	19.4	719.0	100	8.6	734.5	98.7	15.8
20	TRUE	19	50	651.4	89.4	30.4	734.1	85.6	25.6	685.4	93.4	21.5
21	TRUE	20	400	589.6	100	10.2	534.1	97.4	14.2	544.8	95.6	15.5
22	TRUE	18	150	501.2	95.8	20.4	507.4	94.4	19.5	535.8	90.0	21.6

23	TRUE	19	50	803.2	98.6	17.4	657.5	96.7	19.0	657.7	97.8	14.7
24	TRUE	19	250	548.2	93.0	16.9	522.1	91.1	20.7	535.5	90.2	18.9

Mean reaction time dataset

Num	Type	Time
1	control	549.1
2	control	504.4
3	control	407.5
4	control	431.2
5	control	379.1
6	control	418
7	control	411.3
8	control	495.5
9	control	543.2
10	control	556.3
11	control	520.6
12	control	489.7
13	control	460.3
14	control	727.3
15	control	640.6
16	control	672.1
17	control	500.7
18	control	736.7
19	control	750.1
20	control	651.4
21	control	589.6
22	control	501.2
23	control	803.2
24	control	548.2
25	minor	550.7
26	minor	494.5
27	minor	391.2
28	minor	402.1
29	minor	371.8

30	minor	442.6
31	minor	404
32	minor	454
33	minor	518.7
34	minor	547.6
35	minor	498.7
36	minor	508.9
37	minor	520.1
38	minor	636.2
39	minor	634.8
40	minor	628
41	minor	491.5
42	minor	719.2
43	minor	719
44	minor	734.1
45	minor	534.1
46	minor	507.4
47	minor	657.5
48	minor	522.1
49	major	495.4
50	major	510.3
51	major	381.7
52	major	375
53	major	400.6
54	major	404.6
55	major	401.2
56	major	464.3
57	major	495.4
58	major	563.7
59	major	488.5
60	major	485.5
61	major	527.1
62	major	649.6
63	major	685.7
64	major	651.4

65	major	527
66	major	620
67	major	734.5
68	major	685.4
69	major	544.8
70	major	535.8
71	major	657.7
72	major	535.5

Accuracy dataset

Num	Type	Percent
1	control	98.2
2	control	95.1
3	control	93.1
4	control	91.3
5	control	91.9
6	control	86.5
7	control	87.7
8	control	88.3
9	control	94.7
10	control	97.2
11	control	95.7
12	control	99
13	control	97.4
14	control	94.3
15	control	98.9
16	control	98.8
17	control	89.9
18	control	92.3
19	control	98.7
20	control	89.4
21	control	100
22	control	95.8
23	control	98.6

24	control	93
25	minor	100
26	minor	90.8
27	minor	89.8
28	minor	89.6
29	minor	89.3
30	minor	77.1
31	minor	86.7
32	minor	91.4
33	minor	92.7
34	minor	96.4
35	minor	94.4
36	minor	98.3
37	minor	93.4
38	minor	96.8
39	minor	98.9
40	minor	98.9
41	minor	89
42	minor	97.6
43	minor	100
44	minor	85.6
45	minor	97.4
46	minor	94.4
47	minor	96.7
48	minor	91.1
49	major	95.8
50	major	98.3
51	major	89.1
52	major	90.1
53	major	87.5
54	major	88.3
55	major	91.4
56	major	92.6
57	major	94.4
58	major	97.2

59	major	89.6
60	major	97.3
61	major	96.6
62	major	94.6
63	major	100
64	major	100
65	major	82.4
66	major	91.4
67	major	98.7
68	major	93.4
69	major	95.6
70	major	90
71	major	97.8
72	major	90.2

Appendix D. Statistics full information

Descriptive information about the mean reaction time data set:

```
  Type     count  mean    sd
    <fct>    <int> <dbl> <dbl>
1 control     24  554.  119.
2 major       24  534.  104.
3 minor       24  537.  105.
```

Descriptive information about the accuracy data set:

```
  Type     count  mean    sd
    <fct>    <int> <dbl> <dbl>
1 control     24  94.4  4.05
2 major       24  93.4  4.51
3 minor       24  93.2  5.47
```

Pairwise T-test Full Information

	No - Minor	No - Major	Minor - Major
Mean Reaction Time	data: Time by Type t = 1.8262, df = 23, p-value = 0.9596 alternative hypothesis: true mean difference is less than 0 95 percent confidence interval: -Inf 32.18723 sample estimates: mean difference 16.60417	data: Time by Type t = 1.9305, df = 23, p-value = 0.967 alternative hypothesis: true mean difference is less than 0 95 percent confidence interval: -Inf 36.70162 sample estimates: mean difference 19.44167	data: Time by Type t = -0.41376, df = 23, p-value = 0.3414 alternative hypothesis: true mean difference is less than 0 95 percent confidence interval: -Inf 8.915978 sample estimates: mean difference -2.8375
Accuracy	data: Percent by Type t = 2.0679, df = 23, p-value = 0.02504 alternative hypothesis: true mean difference is greater than 0 95 percent confidence interval: 0.210437 Inf sample estimates: mean difference 1.229167	data: Percent by Type t = 1.4748, df = 23, p-value = 0.07691 alternative hypothesis: true mean difference is greater than 0 95 percent confidence interval: -0.1587154 Inf sample estimates: mean difference 0.9791667	data: Percent by Type t = 0.28016, df = 23, p-value = 0.3909 alternative hypothesis: true mean difference is greater than 0 95 percent confidence interval: -1.279388 Inf sample estimates: mean difference 0.25

Revised Pairwise T-test for Mean Reaction Time Full Information

	No - Minor	No - Major	Minor - Major
Mean Reaction Time	data: Time by Type t = 1.8262, df = 23, p-value = 0.04042	data: Time by Type t = 1.9305, df = 23, p-value = 0.03298	data: Time by Type t = -0.41376, df = 23, p-value =

	alternative hypothesis: true mean difference is greater than 0 95 percent confidence interval: 1.021103 Inf sample estimates: mean difference 16.60417	alternative hypothesis: true mean difference is greater than 0 95 percent confidence interval: 2.181714 Inf sample estimates: mean difference 19.44167	0.6586 alternative hypothesis: true mean difference is greater than 0 95 percent confidence interval: -14.59098 Inf sample estimates: mean difference -2.8375

Appendix E: Full R Code

```
data_rt <- read.csv("reactionTime.csv", sep = ",", header = T,
stringsAsFactors = T)
data_acc <- read.csv("accuracy.csv", sep = ",", header = T, stringsAsFactors =
T)

install.packages("dplyr")
install.packages("ggplot2")
install.packages("car")
install.packages("gplots")
install.packages("ggpubr")

library(alr3)
library(ggplot2)
library(car)
library(dplyr)
library(gplots)
library("ggpubr")

#Reordering labels
data_rt$Type <- ordered(data_rt$Type, levels = c("control", "minor", "major"))
data_acc$Type <- ordered(data_acc$Type, levels = c("control", "minor",
"major"))

#Check labels
levels(data_rt$Type)
levels(data_acc$Type)

#Get Means and SD of data
group_by(data_rt, Type) %>%
  summarise(count = n(), mean = mean(Time, na.rm= TRUE), sd = sd(Time, na.rm =
TRUE))

group_by(data_acc, Type) %>%
  summarise(count = n(), mean = mean(Percent, na.rm= TRUE), sd = sd(Percent,
na.rm = TRUE))

#Box Plots
boxplot_rt <- ggplot(data_rt, aes(x = Type, y=Time, color=Type)) +
geom_boxplot()
boxplot_acc <- ggplot(data_acc, aes(x = Type, y=Percent, color=Type)) +
geom_boxplot()

boxplot_rt
boxplot_acc

#Mean Plots
ggline(data_rt, x = "Type", y = "Time",
       add = c("mean_se", "jitter"),
       order = c("control", "minor", "major"),
       ylab = "Time", xlab = "Type")

ggline(data_acc, x = "Type", y = "Percent",
       add = c("mean_se", "jitter"),
       order = c("control", "minor", "major"),
```

```
       ylab = "Percent", xlab = "Type")

# ----- ANOVA Test -----
anova_rt <- aov(Time ~ Type,data= data_rt)
anova_acc <- aov(Percent ~ Type, data= data_acc)

summary(anova_rt)
summary(anova_acc)

# Tukey comparision for each ANOVA table
TukeyHSD(anova_rt)
TukeyHSD(anova_acc)

#Check homogeneity
plot(anova_rt, 1)
plot(anova_acc, 1)

leveneTest(Time ~ Type, data = data_rt)
leveneTest(Percent ~ Type, data = data_acc)

#Check normality
plot(anova_rt, 2)
plot(anova_acc, 2)

aov_rt_res <- residuals(object = anova_rt)
shapiro.test(x = aov_rt_res)

aov_rt_acc <- residuals(object = anova_acc)
shapiro.test(x = aov_rt_acc)

#Drop outliers
data_rt_2 <- data_rt[-c(23,44,67), ]
anova_rt_2 <- aov(Time ~ Type,data= data_rt_2)

plot(anova_rt_2, 1)
leveneTest(Time ~ Type, data = data_rt_2)

plot(anova_rt_2, 2)
aov_rt_res_2 <- residuals(object = anova_rt_2)
shapiro.test(x = aov_rt_res_2)

# ----- Pairwise Comparisons -----

#Reaction Time
rt_pair_1 <- data_rt %>% filter(Type == "control" | Type == "minor")
rt_pair_2 <- data_rt %>% filter(Type == "control" | Type == "major")
rt_pair_3 <- data_rt %>% filter(Type == "major" | Type == "minor")

rt_test_1 <- t.test(Time ~ Type, data = rt_pair_1, paired = TRUE, alternative
= "greater")
rt_test_1

rt_test_2 <- t.test(Time ~ Type, data = rt_pair_2, paired = TRUE, alternative
= "greater")
```

```
rt_test_2

rt_test_3 <- t.test(Time ~ Type, data = rt_pair_3, paired = TRUE, alternative
= "greater")
rt_test_3

#Accuracy
acc_pair_1 <- data_acc %>% filter(Type == "control" | Type == "minor")
acc_pair_2 <- data_acc %>% filter(Type == "control" | Type == "major")
acc_pair_3 <- data_acc %>% filter(Type == "major" | Type == "minor")

acc_test_1 <- t.test(Percent ~ Type, data = acc_pair_1, paired = TRUE,
alternative = "greater")
acc_test_1

acc_test_2 <- t.test(Percent ~ Type, data = acc_pair_2, paired = TRUE,
alternative = "greater")
acc_test_2

acc_test_3 <- t.test(Percent ~ Type, data = acc_pair_3, paired = TRUE,
alternative = "greater")
acc_test_3
```

Attribution Table:

RS – Research
WD – Wrote Draft
MR – Major Revision
ET – Edited
FP – Final Proofread of COMPLETE DOCUMENT for flow and consistency
GC – General Contribution (for tasks that don't involve writing and editing)
RC – R coding
DC – Data Collection

Tasks:	**Houman**	**Joaquin**	**Janoshan**	**Danny**
Introduction	RS, WD	RS, WD	RS, WD, MR	RS, WD
Methods - Variables/Context	WD	WD, ET	RS, WD	MR, ET
Methods - Procedure	WD	WD, ET, DC	ET	WD, MR, ET, DC
Analysis	WD	WD	ET	MR, RC
Results	WD	WD, MR, ET	ET	WD, MR, ET
Conclusion	WD	WD, MR, ET	ET	ET, MR
References		WD	WD	
Appendix	WD, ET	WD, ET	ET	ET

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