Hypothesis Testing: Argus II retinal prosthesis

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The Question

We are primarily interested in understanding if the Argus II retinal prosthesis was effective in improving the subject's vision. The mean of the magnitude of difference between the target and the location of where the participant touched the screen. We want to see if the distance between where the participiant touched and the center is smaller with the system on?

Each participant has the mean of 40 trials of the value for when the system is on and when the system is off. The data is continuous.

Determine your null hypothesis, alternative hypothesis, alpha value

Null Hypothesis (H0): Argus II has no effect on people's vision. If the null hypothesis were true, there would be no change in distance for partiipaints. distanceOn - distanceOff = 0

Alternative hypothesis: Argus II had an effect on people's vision (the mean of the magnitude of difference between the target and where the participant touched the screen is different for system on and system off). DistanceOn - DistanceOff != 0

Alpha value: .05

Conduct your experiment and collect your data (Load Data).

```
data = readtable("argusData.csv") %import data
```

data = 29×3 table

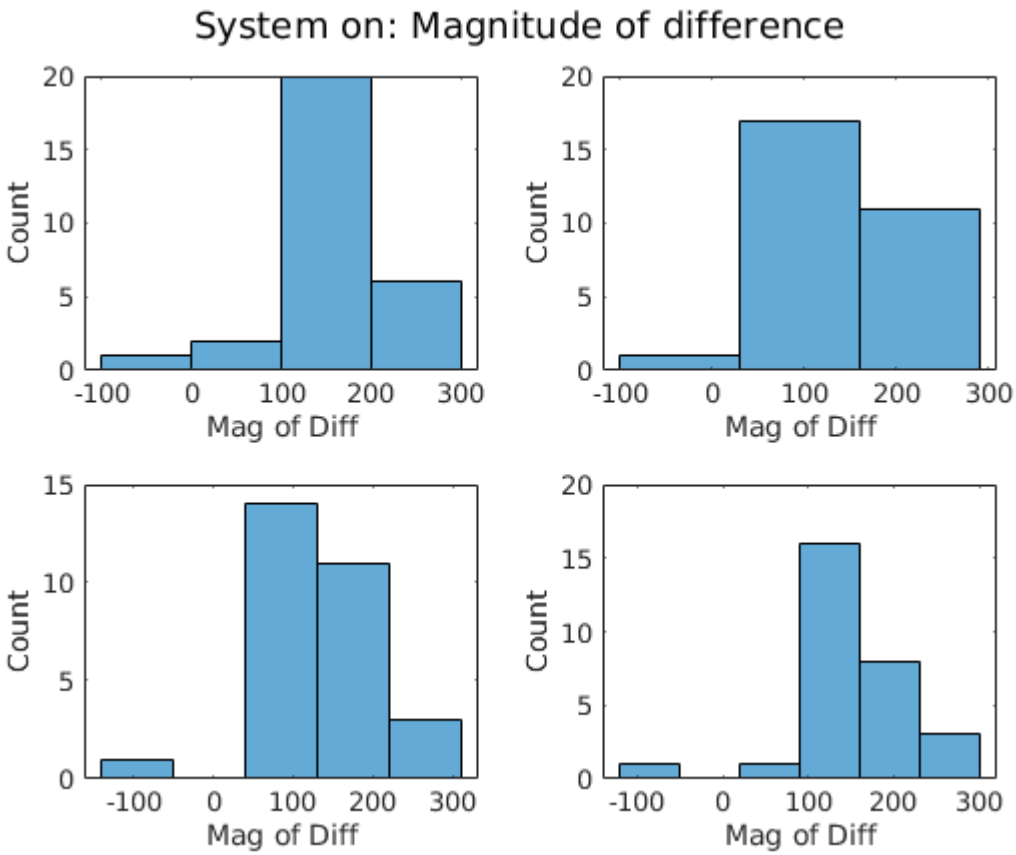
	Participant	SystemOn	SystemOff
1	'A'	128	372
2	'B'	115	319
3	'C'	177	324
4	'D'	106	343
5	'E'	121	385
6	'F'	201	382
7	'G'	178	300
8	'H'	190	181
9	'I'	122	347
10	'J'	120	386
11	'K'	112	209
12	'L'	211	-1
13	'M'	103	404
14	'N'	102	536

Organize and clean the data

Understanding The Data

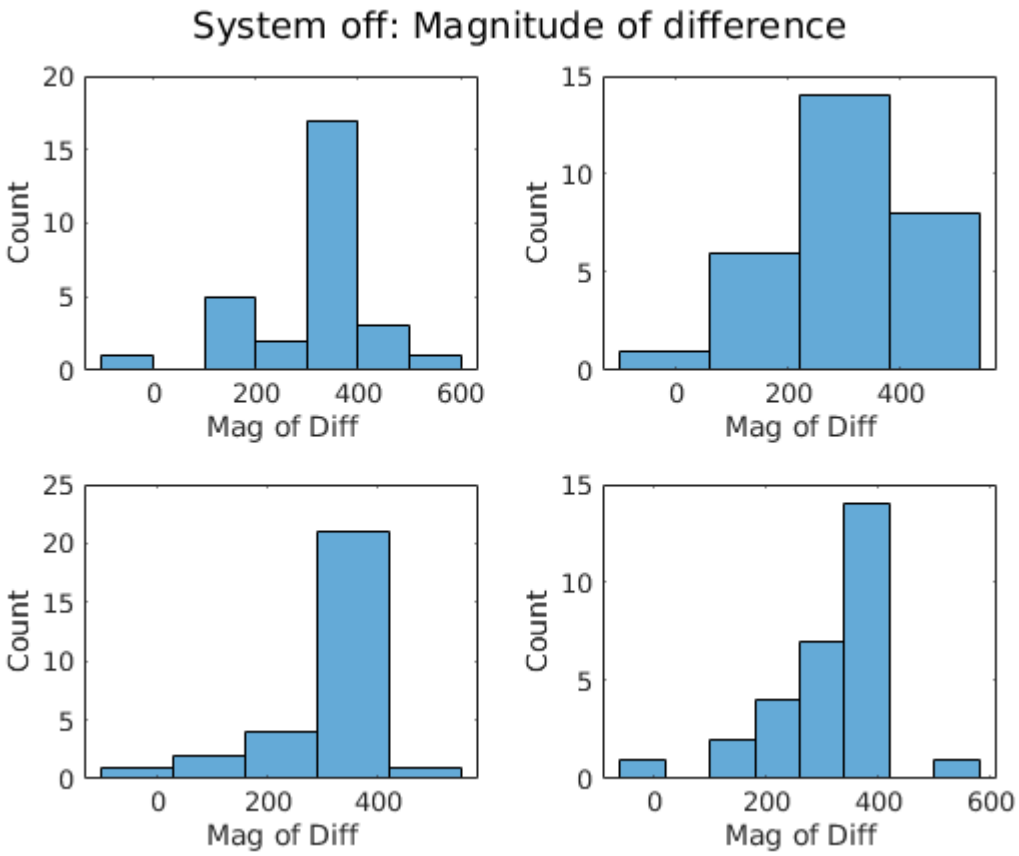
Participants are represented by Strings 'A' to 'AC'. There is a mean of 40 trials for both the system on and system off for each participant.

```
%Get an understanding of the distrubution: System On
figure();
sgtitle("System on: Magnitude of difference")
subplot(2,2,1)
histogram(data.SystemOn)
xlabel("Mag of Diff"); ylabel("Count");
subplot(2,2,2)
histogram(data.SystemOn, 3)
xlabel("Mag of Diff"); ylabel("Count");
subplot(2,2,3)
histogram(data.SystemOn, 5)
xlabel("Mag of Diff"); ylabel("Count");
subplot(2,2,4)
histogram(data.SystemOn, 6)
xlabel("Mag of Diff"); ylabel("Count");
```




```
%Get an understanding of the distrubutionL System Off
```

```
figure();
sgtitle("System off: Magnitude of difference")
subplot(2,2,1)
histogram(data.SystemOff)
xlabel("Mag of Diff"); ylabel("Count");
subplot(2,2,2)
histogram(data.SystemOff,4)
xlabel("Mag of Diff"); ylabel("Count");
subplot(2,2,3)
histogram(data.SystemOff, 5)
xlabel("Mag of Diff"); ylabel("Count");
subplot(2,2,4)
histogram(data.SystemOff, 8)
xlabel("Mag of Diff"); ylabel("Count");
```



Looking at the histograms, we see there are negative values. This is not expected as the values are "the mean of the magnitude of difference." Below, I am looking closer into the negative values (based on the data I would expect everything to be >=0 but that is not the case). These values are not expected so they will be considered outliers, and not used in the testing.

Investiage (and Remove) Outliers

```
%see (the number of and values of) negative data in both SystemOn and
%SystemOff
data(data.SystemOn < 0, :)
```

ans = 1×3 table

	Participant	SystemOn	SystemOff
1	'X'	-99	136

ans = 1×3 table

	Participant	SystemOn	SystemOff
1	'L'	211	-1

```
data(data.SystemOff < 0, :)
```

Looking at the tables, we see there is one value for system on and one value for system off that is negative. As such, we will remove this data. Note, we remove the whole line of data (all data for that participant) since it is a paired experiment.

```
%Remove outliers
data(data.SystemOff<0,:) = [];
data(data.SystemOn<0,:) = [];

%look at the summary of the data
summary(data)
```

```
Variables:

    Participant: 27×1 cell array of character vectors

    SystemOn: 27×1 double

        Values:

            Min          72
            Median      128
            Max         268

    SystemOff: 27×1 double

        Values:

            Min         136
            Median      343
            Max         536
```

Reviewing Data

Now that we removed outliers, we will visualize our data again. This time, since we are interested in the difference of pixel distance for each participant between SystemOn and SystemOff, we will create a column in the table that holds this distance. This will also be what we plot on the histogram. Note: distance will be SystemOff - SystemOn so a positive value indicates an improvement when the system is on.

```
data.Diff = data.SystemOff - data.SystemOn
```

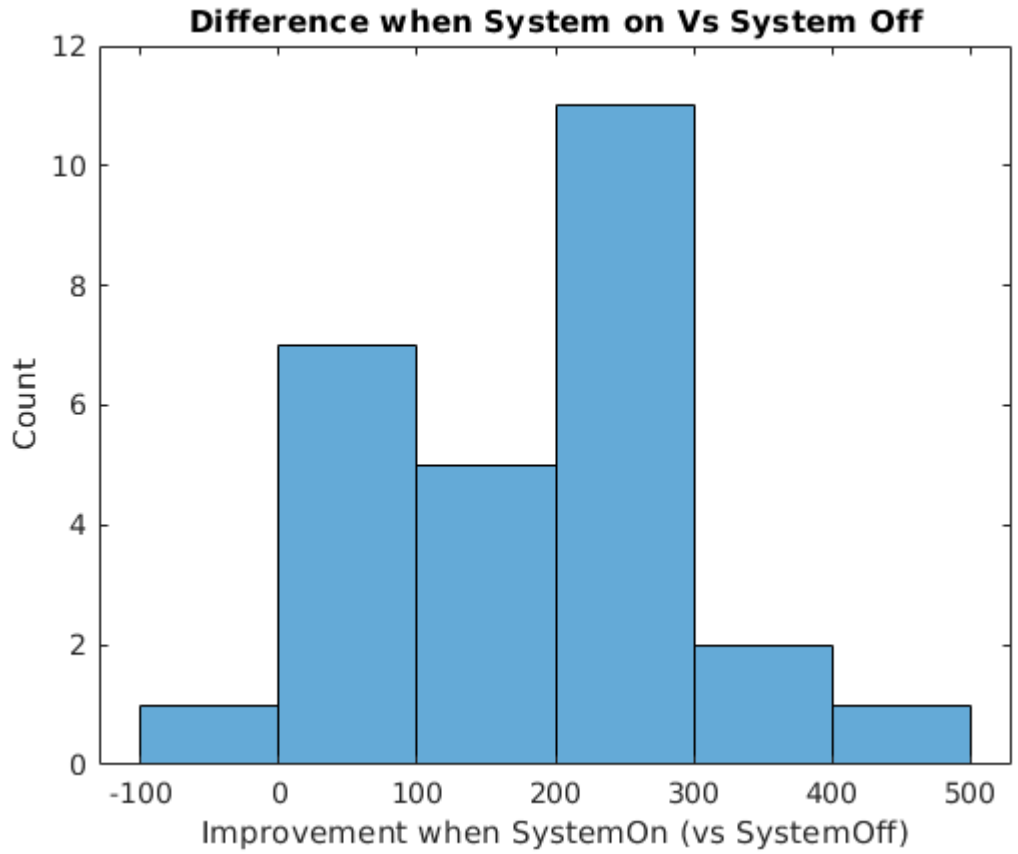
data = 27×4 table

	Participant	SystemOn	SystemOff	Diff
1	'A'	128	372	244
2	'B'	115	319	204

	Participant	SystemOn	SystemOff	Diff
3	'C'	177	324	147
4	'D'	106	343	237
5	'E'	121	385	264
6	'F'	201	382	181
7	'G'	178	300	122
8	'H'	190	181	-9
9	'I'	122	347	225
10	'J'	120	386	266
11	'K'	112	209	97
12	'M'	103	404	301
13	'N'	102	536	434
14	'O'	199	327	128

⋮

```
figure()
histogram(data.Diff)
xlabel("Improvement when SystemOn (vs SystemOff)")
ylabel("Count")
title("Difference when System on Vs System Off")
```



Looking at the histrogram, we it is a relatively normal distrubtion (this will be tested in the next section) and the SystemOn improves the accuracy for most participsants.

Determine what types of tests/measurements are appropriate to answer your question.

We have a set of data for each participant with using the Argus II and a set of data without using the Argus II. Therefore, I will use a **paired sample T test.**

Assumptions of a paired sample T test:

- The dependent variable must be continuous (interval/ratio).
- The observations are independent of one another.
- The dependent variable should be approximately normally distributed.
- The dependent variable should not contain any outliers.

Test for normal distribution of the SystemOn vs SystemOff difference using lillietest:

```
[h, p] = lillietest(data.Diff)
```

```
h = 0
p = 0.1602
```

Based on the results from the lilietest (and from visually looking at the histograms), we see that the difference between SystemOn and SystemOff per subject is normally distributed. Thus, we will proceed with the paired sample T test.

Calculate appropriate measurements / tests

To reiterate our null hypothesis: H0 is that the Argus II has no effect on people's accuracy while performing this task (which would suggest it has no impact on people's vision).

```
%Perform the paired sample T Test

%run paired t test
alpha = .05;
[H, P, CI, STATS] = ttest(data.SystemOff, data.SystemOn, "Alpha", alpha)
```

```
H = 1
P = 1.5414e-09
CI = 2×1
  139.2520
  220.8221
STATS = struct with fields:
    tstat: 9.0737
       df: 26
       sd: 103.1002
```

Understanding the Output of Paired T Test

H = 1 means we *reject the null hypothesis* with our alpha value (currently .05). P is the p-value (the probability of getting our test statistic) or data more extreme given that our null hypothesis is true. As our p-value shows, the data is very unlikely if the null hypothesis is true, so we reject the null hypothesis.

CI is the confidence interval, which in this case is a 95% confidence interval (1 - alpha). In this case, there is a 95% probability that any given confidence interval from a random sample will contain the true population mean. The lower bound is 139.2520 and the upper bound is 220.8221 (pixels).

The STATS gives some other information. As shown, the t-value is 9.0737. A t-value of 0 indicates that the sample results exactly equal the null hypothesis. As the effect size (difference between the sample estimate and null hypothesis) increases, the absolute value of the t-value increases. This t-value, once again, tells us we should reject the null hypothesis. We have 26 degrees of freedom, which is the total number of observations (we got rid of those with a negative value) minus one (so 28 - 1 = 27). The sample standard deviation is 103.1002.

Effect Size

We will use the Cohen's d measure of effect size:

```
cohensd = mean(data.Diff) / STATS.sd
```

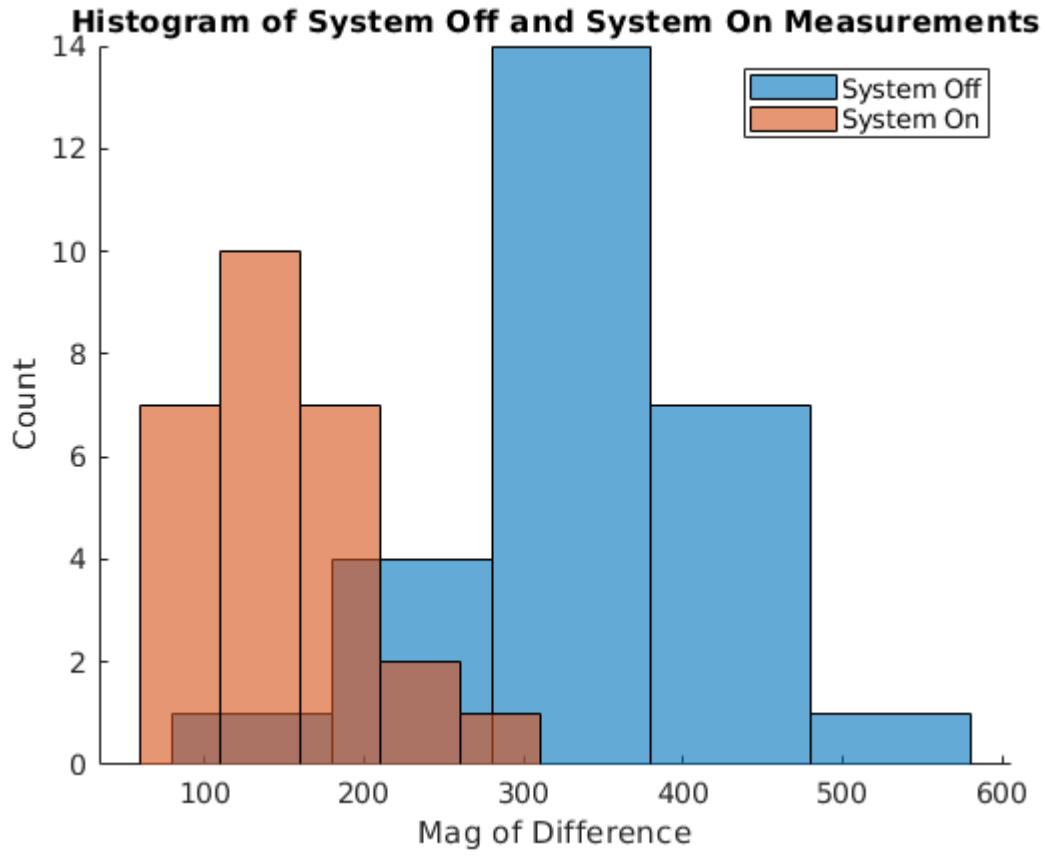
```
cohensd = 1.7462
```

This effect size is very large. Note how .8 is often considered a "large" effect size, and our effect size is 1.7462. This value is the number of standard deviations we observe in our data.

Graph to illustrate findings.

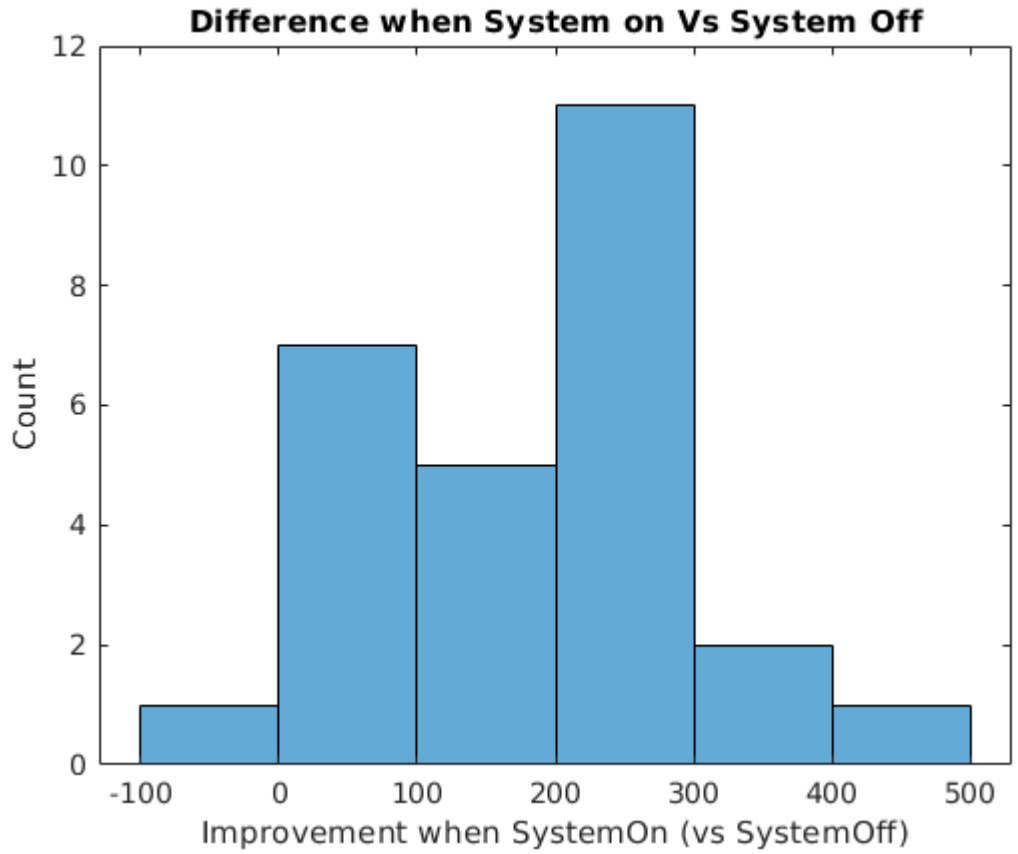
To give a better sense of the findings, below are several different graphs to illustrate the findings.

```
figure();
hold on;
histogram(data.SystemOff,5)
histogram(data.SystemOn,5)
title("Histogram of System Off and System On Measurements")
xlabel("Mag of Difference")
ylabel("Count")
legend("System Off", "System On")
hold off;
```



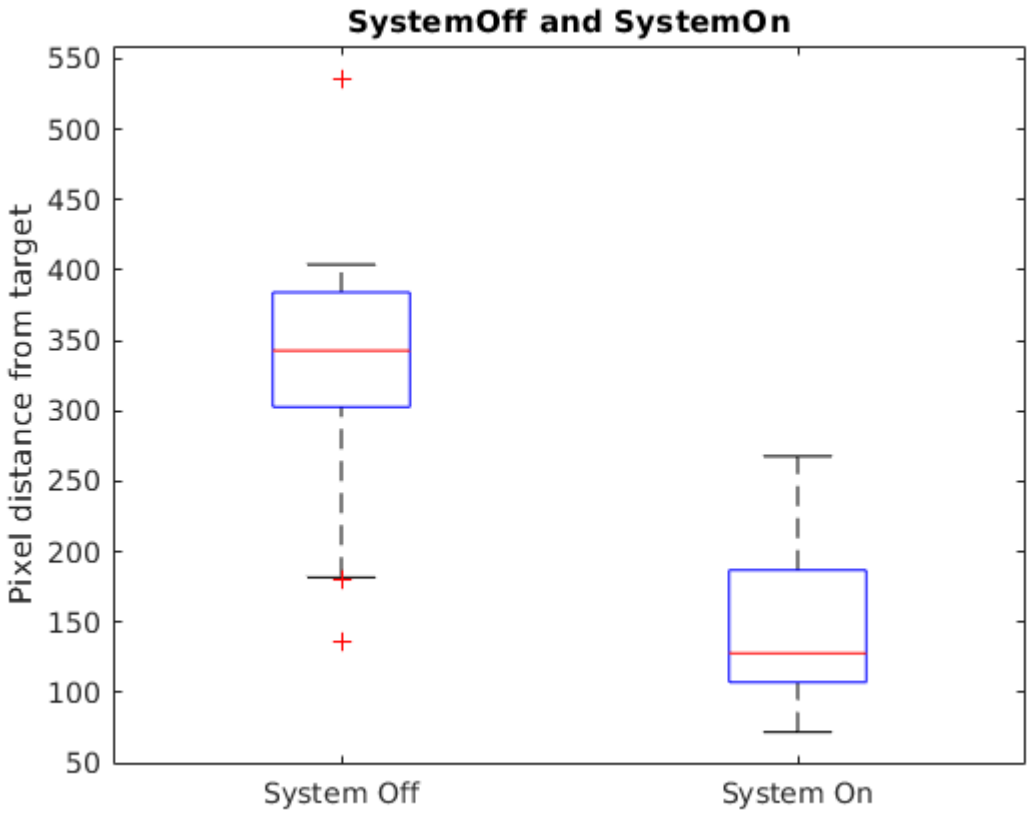
This histogram illustrates the differences (overall) in results between using the Argus II system and not using it. As shown in the graph, there is a small amount of overlap between the measurements of the magnitude of the difference of system on and system off. The data only overlapping slightly makes sense as we rejected the null hypothesis, meaing that there is a significant difference in measurements between using Argus II and not using Argus II. Furthermore, we can see that, overall, using the Argus II system results in a smaller difference in the distance, meaning it improves people's accuracy.

```
histogram(data.Diff)
xlabel("Improvement when SystemOn (vs SystemOff)")
ylabel("Count")
title("Difference when System on Vs System Off")
```



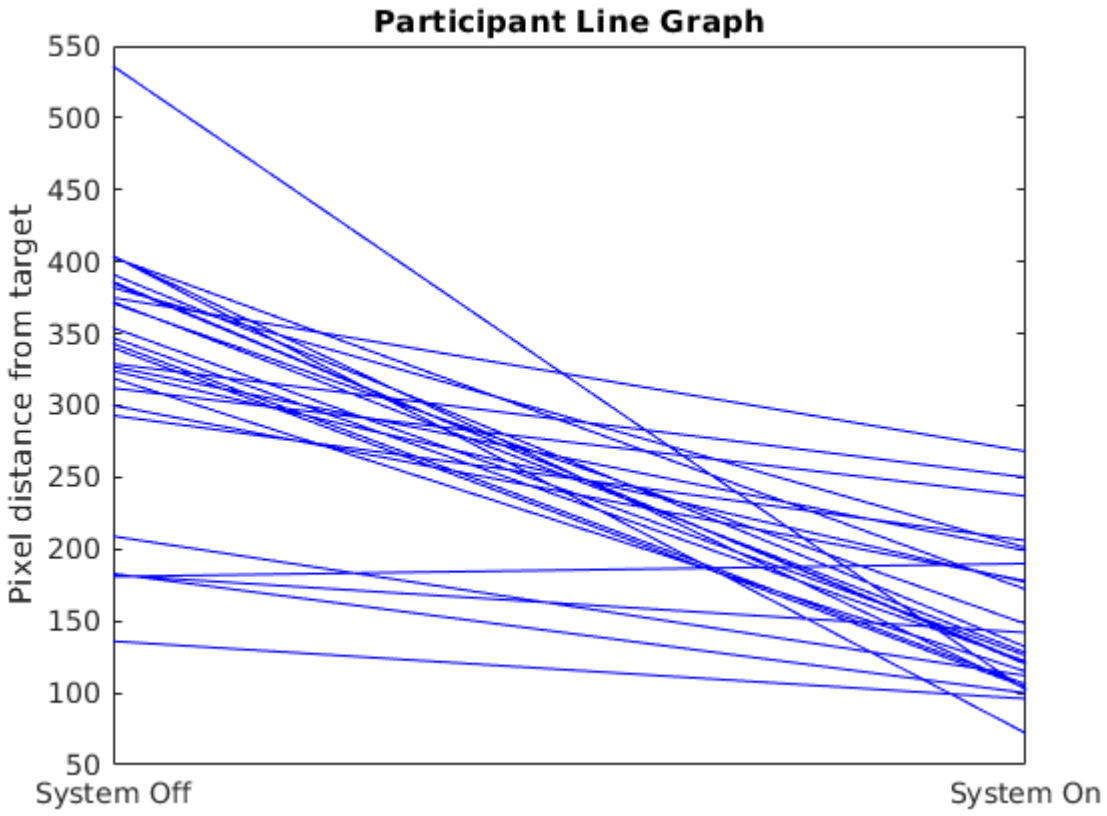
Above is a histogram showing of the diference per subject between SystemOn and SystemOff. As shown, overall, using Argus II improved the accuracy of the subjects. The use of the system only decreased accuracy for one subject, while all other subjects had improved accuracy while using the system.

```
boxplot([data.SystemOff data.SystemOn])
title("SystemOff and SystemOn")
xticklabels(["System Off", "System On"])
ylabel("Pixel distance from target")
```



We can also visualize this with a boxplot for systemOn and systemOff. This shows some key data points (lower extreme, lower quartile, median, upper quartile, and upper extreme) for the pixel distance from target for both System On and System Off. As shown (and expected), the System On had lower pixel distances from target than System Off. The median distance for System Off is about 340 pixels while the median distance for System On is about 125 pixels.

```
plot([data.SystemOff data.SystemOn]', 'b');
xticks([1 2])
xticklabels(["System Off", "System On"])
ylabel("Pixel distance from target")
title("Participant Line Graph")
```



The above graph is a line graph where we can easily visualize the difference between System Off and System On for each participant. In this graph, each participant is a line. This graph shows the difference for each participant between System Off and System On. The pixel distance from target while System Off is almost always higher (in all but one case) than the distance when System is On. This graph allows an easy visualization of how the system impacted each subject, as opposed to the other graphs where more aggregate data is shown. Looking at the graph, there seems to be a cluster of subjects whose System Off distance from target was around 325-400 pixels who had a distance of only about 100-150 pixels with system on. Overall, this graph shows the improvement per subject in an easy to interpret and understand format.

Through all of these graphs, we can better understand and visualize our findings. The graphs support the result of the paired T test to reject the null hypothesis. It helps to visualize the differences between using the Argus II system and not using the Argus II system.

Summary of Useful Values

```
mean_improvement = mean(data.Diff)
```

```
mean_improvement = 180.0370
```

```
mean_sys_on = mean(data.SystemOn)
```

```
mean_sys_on = 149.1481
```

```
mean_sys_off = mean(data.SystemOff)
```

```
mean_sys_off = 329.1852
```

```
STATS
```

```
STATS = struct with fields:
    tstat: 9.0737
       df: 26
       sd: 103.1002
```

```
P
```

```
P = 1.5414e-09
```

```
cohensd
```

```
cohensd = 1.7462
```

Summary of Findings

In this study, we compared the impact of using the Argus II Retinal Prosthesis on particpant's accuracy in determining the center of a white square stimulus. The less the magnitude of difference between the center of the stimulus and the participant's location touched, the more accurate they were. These samples were averaged over 40 trials and recorded for SystemOn and SystemOff for each participant. After eliminating outliers, this was analyzed for 27 participants.

When the system was off, the mean distance between the square and location touched was 329.2 pixels, and it was 149.1 pixels when the System was on. The mean improvement was 180 pixels, with a standard deviation of 103.1 pixels. The Cohen's d measure of effect size of 1.7 was calculated, indicating a very large effect size. A paired t-test indicated a significant difference between SystemOff and SystemOn: t(27) = 9.07 with a p value of 2.7e-9. Based on these findings, the null hypothesis was rejected.