**Assignment 1**

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**PSYR 6003: Fundamentals of Applied Statistics**

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**Design Statement**

The following report contains secondary analyses of a historically collected dataset, which contains information about the Avengers’ final battle against Thanos, across two geographically distinct battlefields. All analyses were performed using R Statistical Software (v4.4.2; R Core Team 2024). Original Avengers’ data was obtained from a public GitHub repository (available here: https://github.com/iyakoven/PSYR6003-Assignment-1), and cloned to another public repository before manipulation (available here: https://github.com/mseward96/PSYR6003\_A1)

Data were imported, cleaned, and manipulated using the tidyverse R package (v2.0.0; Wickham et al., 2019), the haven package for tidyverse(v2.5.4; Wickham et al, 2023). Power analysis was conducted using the pwr package for R (v 1.3.0; Champley 2020), equivalence testing using the TOSTER package for R (v 0.8.4; Caldwell 2022; Lakens 2017), and effect size calculations were completed using the effectsize package for R (v1.0.0; Ben-Shachar et al., 2020).

**Methods**

Data were retrieved from a publicly available GitHub repository (available here: https://github.com/iyakoven/PSYR6003-Assignment-1), and cloned to a new repository before manipulation. All data manipulations and analysis code can be found at the cloned GitHub repository (available here: https://github.com/mseward96/PSYR6003\_A1).

Initial data cleaning was completed using the tidyverse package for R (v2.5.4; Wickham et al., 2019). Subsequently, the drop\_na function in tidyverse was used to create a subset of data where all cases with missing values were removed, to ensure accuracy of further analysis. The drop\_na function in tidyverse removes any case with missing values in any column (variable) from the dataset. The nature of this analysis makes the drop\_na function viable, and efficient as we are only interested in complete cases that have data in every variable. The resultant dataset used for the rest of the analysis only contained complete cases and missing values did not need to be accounted for in further analyses.

Recent work suggests that the sum of agility, speed, strength and willpower represents a reliable measure of combat effectiveness. The historical data set did not contain any measure of effectiveness, but did contain values recorded for agility, speed, strength and willpower. Accordingly, we were able to calculate combat effectiveness as the sum of these values, in line with recent evidence. Using the mutate function in the tidyverse package for R (v2.5.4; Wickham et al 2019) this combat effectiveness score was calculated by summing the variables listed prior, and a new dataset was created which contained the new variable as an additional column.

**Results**

In an exploratory analysis, we investigated the characteristics of Avengers with no superpowers that died during the battle, with a specific interest in any potential differences between the north and south battlefields. To do so, created a new data subset by selecting only cases who had no superpowers and that had died, and exported this new dataset to both .csv and .sav formats using the haven package for tidyverse, for ease of future analysis by other groups (data available here: https://github.com/mseward96/PSYR6003\_A1). With the new dataset, we calculated summary descriptive statistics for the overall sample, followed by a subsequent analysis that split the outcome by battlefield geography (north, south). Overall results are presented in table 1, and the descriptive statistics for each battlefield are available in table 2. It appears that regarding combat effectiveness, the north battlefield was more effective, evidenced by the north battlefield having a greater mean effectiveness score. The north battlefield also saw a higher number average in number injuries, which may be a surprising result given the higher average combat effectiveness (you may expect more effective fighters to get injured less). This unexpected result may be due to error in the mean model for combat effectiveness scores, given that the standard deviation and standard error values for combat effectiveness are very high, making combat effectiveness the most erroneous variable in the mean model and thus potentially unreliable.

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See Table 1

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See Table 2

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**Superpowers and IQ**

Subsequently, we carried out a further analysis of the entire Avengers’ data set. This second analysis aimed to investigate the association between having superpowers and IQ, and it was hypothesized that Avengers with superpowers would have a higher average IQ than those without superpowers. Before undertaking this analysis, we went back to the data set to ensure that we had appropriate statistical power to conduct such an analysis. Prior “rule of thumb” standards in the field of IQ research indicate that our sample size is justified, however, to conserve resources and ensure meaningful results we chose to conduct an a priori power analysis to determine the sample size needed to detect an effect.

This field lacks prior meta-analyses or large studies on which to base estimations of expected effect size. However, based on similar research (superpowers being associated with higher brain volumes, faster processing speeds, memory advantages) which indirectly associate superpowers with higher IQ with medium effects, our theoretical prediction is that superpowers will have a medium effect (d = 0.5) on average IQ. Using this theoretical prediction, we conducted an a priori power analysis using the pwr package for R (v 1.3.0; Champley 2020). As mentioned above, we chose to power for a medium effect of Cohen’s d = 0.5, and we set alpha at 0.05 and selected a power level of 80%, based on standards in the field. Using the parameters described above, the resulting power analysis for an independent samples *t* test determined that a total of 64 participants per group would be required to detect an effect of d = 0.5 at an alpha of 0.05 and 80% power.

Another prevailing theory is that superpowers have no effect on IQ. Therefore, for this study, we also wanted to ensure that the sample was adequately powered not just to detect an effect, but also to accurately detect no difference between groups. It is impossible to show that an effect size is exactly zero, however you test for an equivalence range where values are too small to be interpreted/ can be interpreted as zero. To determine the group size needed to detect no effect we carried out equivalence testing. Two one sided tests (TOST) were conducted using the TOSTER package for R (v 0.8.4; Caldwell 2022; Lakens 2017). Using identical parameters to our power analysis, with alpha =.05, power at 80% and the upper and lower equivalence bounds at -0.5, and 0.5 respectively for an effect size of d = 0.5, we determined that there would need to be at least 69 participants per group to confirm if there is truly zero effect.

Finally, we conducted an independent samples *t* test to compare the average IQ between Avengers with superpowers and without superpowers; *t =* 4.25. To test our hypotheses about superpowers having a medium effect on IQ, we calculated an effect size for this t statistic. Using the effectsize package for R(v1.0.0; Ben-Shachar et al., 2020), we input *t =* 4.25*,* and the group sizes for no superpowers (N=780) and for the superpowers group (N=32). We did not confirm our hypothesis about a medium effect and instead found that superpowers have a small effect (d=0.30, 95% CI [0.16, 0.44]) on IQ. We do not feel that this finding of a small effect is precise given that the one of the groups does not meet the size threshold (N=64) we calculated with our power analysis. Finally, the 95% confidence interval for d=0.30 contains a wide range of values which cover very small effect sizes of d =.16, with effect sizes that trend towards medium at d = 0.44. Future research should strive to recruit appropriately powered groups to detect the effect of superpowers on IQ.

**References**

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**Table 1:**

Summary Statistics for all dead Avengers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Measure | M | SD | Range (Min - Max) | SE |
| Kills | 2.55 | 8.81 | 0 - 79 | 0.88 |
| Injuries | 4.55 | 0.74 | 2 - 5 | 0.07 |
| Combat Effectiveness | 497.5 | 177.6 | 67.3 - 946.9 | 17.7 |

**Table 2:**

|  | **North** |  |  | **South** |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Measures | ***M*** | ***SD*** | ***R*ange** | ***M*** | ***SD*** | ***R*ange** |
| Kills | 1.71 | 4.60 | 0 - 34 | 4.8 | 15.0 | 0 - 79 |
| Injuries | 4.6 | 0.68 | 2 - 5 | 4.4 | 0.90 | 2 - 5 |
| Combat Effectiveness | 499.8 | 174.1 | 130.7 – 897.1 | 491.7 | 189.5 | 67.3 – 946.9 |

Summary Statistics for dead Avengers, by battlefield location.