r/Nootropics Self-Study: Effect of KSM-66 Ashwagandha on Cognitive Performance and Affect

u/MinimumSubject

January 10, 2021

Abstract

This investigation is intended to elucidate the magnitude of Ashwagandha's impact on cognitive performance and affect, explore the time-dependent effects of supplementation and determine by comparing the results obtained to previous work, the extent to which self-experiments could benefit our collective knowledge of nootropics. A brief discussion is also made of pre-existing self-studies found in the r/nootropics subreddit and possible further work.

N.B This self-study is NOT self-blinded (placebo controlled), and I (u/MinimumSubject) am not a doctor or psychologist.

1 Introduction

Within r/nootropics the majority of self-experiment/self-study posts are anecdotal, barring a select few which are discussed in Section 2.1. Although, these posts are interesting and in some cases illuminating, there is only so much that can be qualitatively said about a nootropic before quantification of effects is required to generate further knowledge. Peer-reviewed studies would be the best way to gain this information - but for the majority of nootropics, there is not the grant money to fund research. Therefore, realistically if we as a community want to know how certain nootropics, be that drugs, behaviours (a la meditation or Wim Hof), biotechnology etc., affect us we have to carry out this work ourselves.

Ashwagandha has been purported to enhance memory and cognitive function [31] [29] and decrease anxiety and depressive symptoms [24]. However, as with most nootropics little further work has been done to confirm the extent of these effects, thus new work in this area was considered to be of particular use. As well as this, the study by Pingali et al [**3**] in healthy young men does allow for comparative analysis on Ashwagandha's effect on cognitive performance. Mood and stress level were tracked as a indicator of change in affect [37]; unfortunately, comparison to the literature was impossible.

Section 2 briefly summarises the required psychological and statistical background knowledge and contains my superficial analysis of previous self-experiment posts on r/Nootropics.

Section 3 describes the methods used to collect and analyse the data. The results are shown in Section 4 and discussed in Section 5. My overall conclusions are also presented in Section 5 and Section 6 details possible future studies that could be tackled.

2 Background

Cognitive functioning can be defined as "The individual functional properties regarding a broad range of basal mental operations (i.e., attention, memory, executive functions)." [33] To investigate cognitive performance: attention capacity, rate of information processing, working memory and impulse/inhibitory control were measured through eleven psychometric tests.

Prof. Antonio Damasio defines affect as: the conscious experience of an emotion. [14] However, there is much debate in the literature on how affect is defined, and its relationship to mood and emotion.

2.1 Previous Self-Studies

Searching the nootropics subreddit using the keywords: "self-experiment", "self-study" and "experiment", sorting by relevance, reading posts from only unique users, and discarding question posts, lead to seventeen total posts spread over the course of nine years. I then organised by four categories: anecdotal, did not follow up, self-study (no statistical analysis), self-study (statistical analysis). I have also highlighted where the posts led to a independent website

Three users indicated that they were going to undertake a self-experiment, but never followed up on their original post. Only five users could have been said to have undertaken a n-of-1 study, in which all but two users led to external websites. The rest were regarded as anecdotes.
[For interest: u/Gwern has multiple posts detailing his self-blinded nootropic studies.]

A table of the seventeen posts by category:

Post Title:	User/Name:	Year (2011-20):	Category:
I'm going to start a two week self-experiment with Noopept. I've taken before in 2013, but never the official Russian brand. Any tips for documenting? Anyone know Russian, looking to translate the packaging and notice to English	u/aethelyon	2020	Did not follow up
Does noopept really works - trying to conduct self study	u/Zedmor	2015	Did not follow up
Looking for feedback into performing a very basic blind self-study to determine if reaction time and focus are increased	u/mvisual	2018	Did not follow up
The Effects on Cognition of Sleeping 4 Hours per Night for 12-14 Days: a Pre-Registered Self-Experiment	Alexey Guzey	2020	Self-study (statistical analysis). [Independent Website]
Multiple Posts by u/Gwern	u/Gwern	2013-14	Self-study (statistical analysis). [Independent Website]
Self Experiment: 3 weeks of PRL-8-53 with daily progress testing through CambridgeBrainScience	u/Wow_SuchUsername_	2014	Self-study (no statistical analysis)
I designed a spreadsheet for tracking self-experiments. Here are some of my findings related to nootropics.	u/MrJohnFawkes	2017	Self-study (no statistical analysis). [Independent Website]
Self Experiment: Caffeine on Spatial Recall - No Apparent Benefit or Harm... for Me	u/PasswordIS09876	2011	Self-study (no statistical analysis)
A little self-experiment to gauge effects	u/jacknifejones	2018	Anecdotal
Self Experiment Analysis: caffeine, bcomplex, piracetam, modafinil, bacopa for work productivity	u/thrillseekr	2012	Anecdotal
First experience with Piracetam (One week report)	u/asapviews	2020	Anecdotal
Caffeine. Can you be YOURSELF without it?	u/davem237	2019	Anecdotal
Dopamine conversion to noradrenaline. I've hit a stalemate in my path to heal GAD and depression	u/RTrancid	2020	Anecdotal
My Experience: Piracetam, Oxiracetam, Pramiracetam, and Phenylpiracetam	u/vibage	2016	Anecdotal*
Phenylpiracetam – A Quasi-Scientific Account of High Usage	u/ShortFemaleCEOs	2020	Anecdotal*
Long experience report with p-21	u/DarkTriadBAMN	2017	Anecdotal
Dihydromyricetin - a viable hepaprotective and GABA inhibitor supplement as a sobering agent for alcohol	u/iDrinan	2016	Anecdotal

* refers to posts in which the user indicated to some extent that their post was anecdotal.

It should be noted, that I am not the only one to have suggested a quantitative evolution for r/nootropics. I list below eight noteworthy posts:

Post Title:	User:	Year:	# Upvotes:
This sub is reckless as fuck	u/lentilsoupcan	2019	658
Why Your Nootropics Arent Working	u/anticosmic-overlord	2019	570
I believe an important amount of posters in this subreddit GREATLY underestimate the placebo effect	u/discusssupplements	2016	309
Citizen Science	u/1plusperspective	2015	1
Something is wrong with this sub	u/rondeline	2014	44
Let's make a list of all supplements and interventions backed up by science. Only in humans.	u/edefakiel	2020	445
I created a "Knowledge Map" summarizing the effects of various supplements & nootropics while recommending the ones with solid evidence for actually working	u/FreemanOfficial	2020	259
Thoughts from Three Years in the Game	u/norepinephrinex	2016	288

From this I highlight three main reasons why self-studies are so few and far between:

1. Disciple and motivation issues of the self-experimenter.
2. Difficultly in designing self-experiments and controlling confounding variables.
3. Difficulty of statistical analysis for n-of-1 studies.

I highlight in the section on further work the importance for construction of experimental guidelines and guides for self-studiers, if experiments of this ilk are going to continue and be useful.

Obviously, much work is still required.

2.2 Statistical Background

Required definitions:

Confounding/extraneous variables: "variables, which are not the independent variable, but could affect the results of the experiment." [1]

Student's t-test: this test is used in hypothesis testing if the population is known to be normally distributed but, the variance is unknown. More information can be found here: [35]

The t-score: "Is the ratio between the difference between two groups and the difference within the groups. The larger the t score, the more difference there is between groups. The smaller the t score, the more similarity there is between groups. A t score of 3 means that the groups are three times as different from each other as they are within each other. When you run a t test, the bigger the t-value, the more likely it is that the results are repeatable.

- A large t-score tells you that the groups are different.
- A small t-score tells you that the groups are similar."

[36]

Bayesian estimation is also used alongside a t-test, as it provides more information about the samples and the difference in means than a simple p or t value. "Bayesian estimation for two groups provides complete distributions of credible values for the effect size, group means and their difference, standard deviations and their difference, and the normality of the data." [30]

3 Methods

The experiment took the form of a modified AB design - AB*B. Where A refers to a baseline period and B and B* refer to dosing periods [2]. In a blinded trial, A or B would have been randomly assigned at the start, without the participant's knowledge, as the baseline or dose period. The length of period A was nine days, period B four days and B* was twelve days long.

An ABA type design would have been better (a return to baseline after the dosing period), but due to time constraints and in order to eliminate errors as a result of environmental change, an AB type experiment was chosen.

As Ashwagandha has time-dependent/cumulative effects (ie taking Ashwagandha over a longer period of time increases its effects) [34], the total dosing period was split into B* and B. B* was used to explore Ashwagandha's time-dependent effects, while B was used to determine directly the extent to which Ashwagandha alters cognitive performance and affect. B* can be thought of as a stabilisation period, such that by the time B was reached, peak nootropic effect could be assumed for the duration of the B period.
More time-dependent self-study investigations are included in Section 7.

To keep approximately the same amount of Ashwagandha in my body throughout the daily experiment window, 300mg was taken at 7:10 and 300mg at 14:00 daily during the B and B* period.

Finally, in order to reduce large initial practice effect errors, before formally beginning my self-experiment, two days were spent taking each cognitive test twice. The success of this action is explored further in Sections 4 and 5.

Figure 1: AB*B design. The A period is highlighted in green, the B* period in grey and the B period in red.

3.1 Monitoring Changes in Cognitive Performance

A MacBook Pro 13" 2016 model was used to complete the tasks. Sufficient LED lighting was used. As well as this the curtains to the experiment room were closed and the experimental surface cleared in order to reduce distractions.

N.B Much scrutiny is needed to determine the efficacy and 'correctness' of the approach laid out here.

I decided to only undertake each cognitive tests once a day, to avoid further practice effects.

During each block each test was taken at a different time each day, to ascertain, albeit superficially, the extent to which test taking times effect results and whether Ashwagandha's effects were stable across a fifteen hour (daily) period. Through this the coupling between supplementation and the body's natural cycles could be (again superficially) investigated. [See Circadian Rhythm [38], Cortisol cycle [19] and Ghrelin cycle [13]. There have also be multiple studies to suggest mood has a 24 hour period. [16], [17], [40].]

A random number generator (without replacement) was used to determine when each task would be performed each day.

Factors such as: sleep (duration and quality), calories, exercise and water intake were all monitored, and kept as regular as practicable, to reduce extraneous noise. Food was also consumed at approximately the same times each day, and a regular sleep schedule of 10:30 pm - 7:00 am was adhered to throughout.
My day during this experiment was generally of the form:

Figure 2: Daily routine - from Google Calendar.

Confounding variables tracked:

- Weight (kg)
- H_2O Intake (ml)
- Calorie Intake (kcal)
- Calories Burned (kcal)
- Calorie Deficit (kcal)
- Exercise Minutes (kcal)
- Sleep Regularity (percentage)
- Time Asleep (mins)
- Time Required to Fall Asleep (mins)

N.B Other than a daily multi-vitamin no other nootropics, including caffeine and alcohol, were consumed during the experiment.

3.2 Monitoring Changes in Affect

A google sheets spreadsheet was used to record data. The variables used to track changes in affect were:

- Success [Work] (0 - 4)
- Mood (0 - 4)
- Motivation [Work] (0 - 4)
- Stress (0 - 4)

Six measurements of mood, motivation for work and stress were made at random intervals throughout the day.
Values for success [work] were completed at the end of each day ($\sim 22:00$).

3.3 Cognitive Performance Experiments

All tasks undertaken were sourced from PsyToolkit [21] [32], excepting Dual 'n' Back in which the iPhone app "Dual N-Back" was used.

3.3.1 Deary-Liewald Task

Deary-Liewald is a reaction time task. [39]

Reaction time, in much of the literature, has been found to be significantly correlated with measured intelligence (IQ) - this link has been investigated particularly by Arthur R. Jensen. [4]

3.3.2 Visual Search Task

Visual search tasks requires one to find a visual stimulus amongst other visual stimuli, for example: "searching for a green round bottle among a large collection of bottles". [21]

There has been work suggesting that lower visual search times also correlate with a higher IQ.

3.3.3 Task Switching

The form of task switching test used is detailed by Rogers and Monsell [7]:

"participants switched between 2 tasks on every 2nd trial in 5 experiments and on every 4th trial in a final experiment. The tasks were to classify either the digit member of a pair of characters as even/odd or the letter member as consonant/vowel."

Task switching is an executive function that involves the ability to unconsciously shift attention between one task and another. It is a subcategory of cognitive flexibility. [27]

Executive functions are basic cognitive processes which include: working memory, cognitive flexibility and cognitive inhibition. Reasoning and problem solving are higher-order executive functions. [28]

3.3.4 Posner Cueing Task

The Posner Cueing Task is used to assess the ability of an individual to perform an attention shift. It is widely used as a measure of attention. [26]

It has been found that children with attention deficit hyperactivity disorder (ADHD) have slower reaction times in both valid and invalid trials than neurotypical children. Valid cues inform a participant about the location where something task-relevant will happen, invalid cues occur where nothing relevant will happen. [9]

3.3.5 Stroop Task

The Stroop Task is a widely used psychological test. It measures selective attention capacity, processing speed and cognitive flexibility. It is also used as a component in evaluating an individual's executive functions. [5]

3.3.6 Eriksen-Flanker Task

The Eriksen-Flanker Task is used to assess an individual's ability to suppress responses that are inappropriate in a particular context. [3]

The Eriksen-Flanker Task and Stroop Task are both 'conflict tasks', such that results for both tests should follow the same general trend during the experiment.

It has been shown that exercise can improve performance on Flanker tests. [18]. While acute administration of antihistamine or alcohol severely impairs performance. [23]

3.3.7 Psychological Refractory Period (PRP)

PRP measures the "period of time during which the response to a second stimulus is significantly slowed because the first stimulus is still being processed". [6]

"It measures the limit of dual-tasking, the ability of the cognitive system to complete two tasks in rapid succession, which may be important for goal-directed behavior." [41]

A 2006 study found that alcohol impairs both speed and accuracy of PRP tasks and if caffeine was then supplemented, a reduction in the impairment for speed was noted, but accuracy still remained poor. [15]

3.3.8 Forward and Backward Corsi Block-Tapping Test

Both the forward and backward Corsi Block-Tapping Test assess visuo-spatial short term working memory. [10]

Visuospatial learning disabled (VSLD) children were found to have impaired performance on the Corsi backward task as compared to the forward. [12]

It should be noted that visuospatial deficit is recognized as a common symptom in dyslexics. [22]

3.3.9 Sustained Attention to Response Task (SART)

SART is a go/no-go task that tests impulse/inhibitory control.

"Oops!-Pouring cream into a requested black coffee or throwing away the vegetables while keeping their peelings are examples of action slips common in the everyday lives of normal people [3,21]. Such slips tend to happen when attention to task is degraded through such factors as boredom, worry or dividing attention between several tasks simultaneously. There is a considerable normal variation in action in action-error-proneness [3], and brain damage - particularly to the frontal lobes of the brain - increases the likelihood that individuals will stray from intended goals and hence make errors [33,34]." - From the original SART study by Robertson et al. (1997) [8]

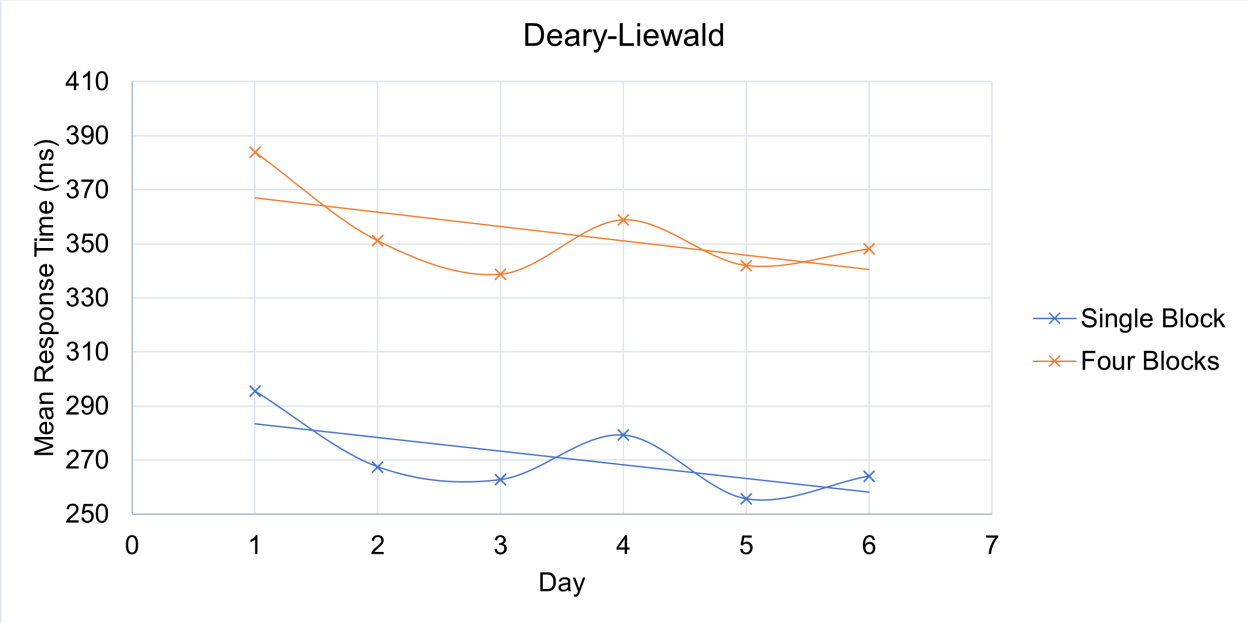
3.3.10 Dual 'n' Back

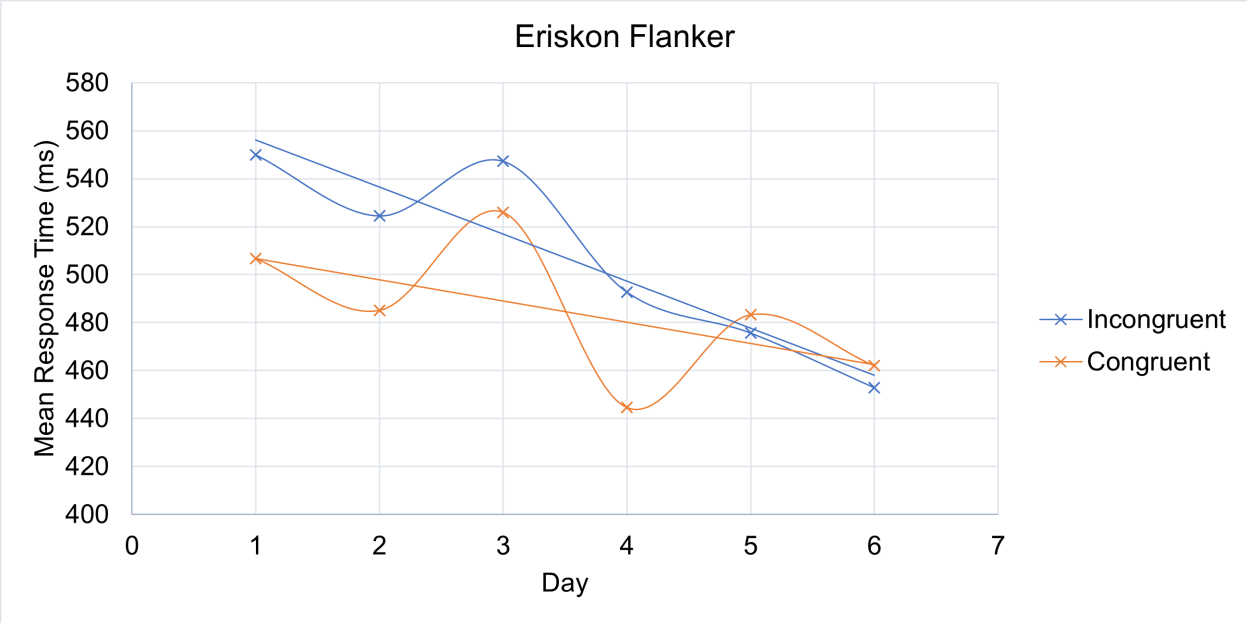
Dual 'n' Back is as test used to measure working memory and working memory capacity. It utilises simultaneous auditory and visual stimuli. [20]

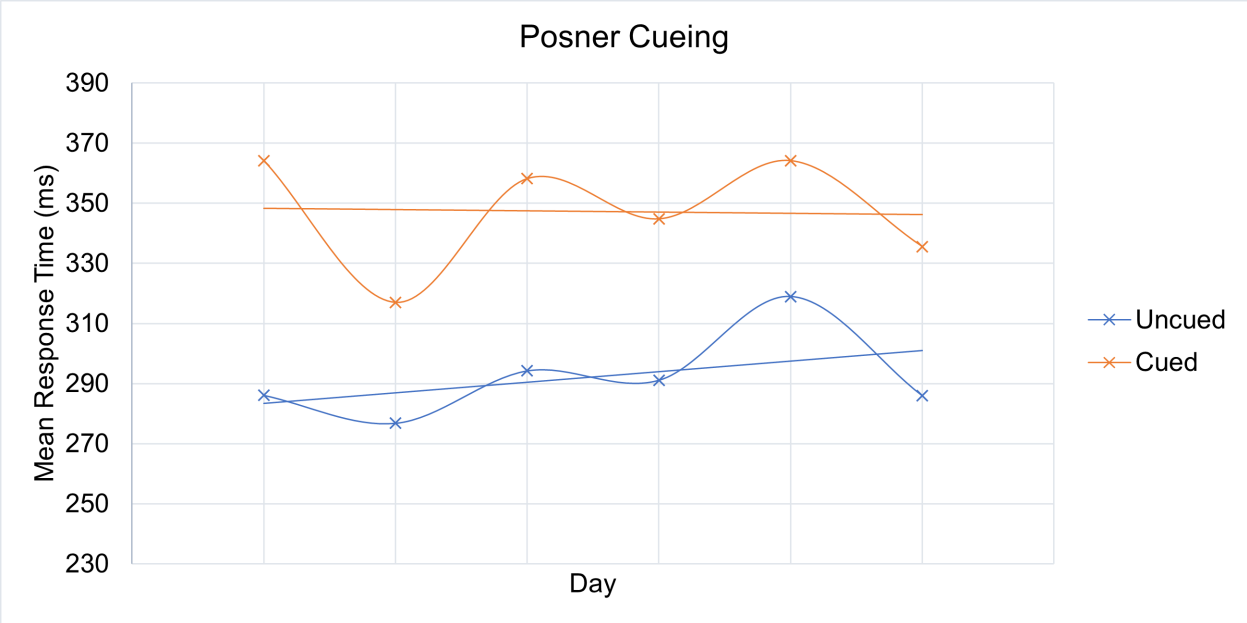
4 Results

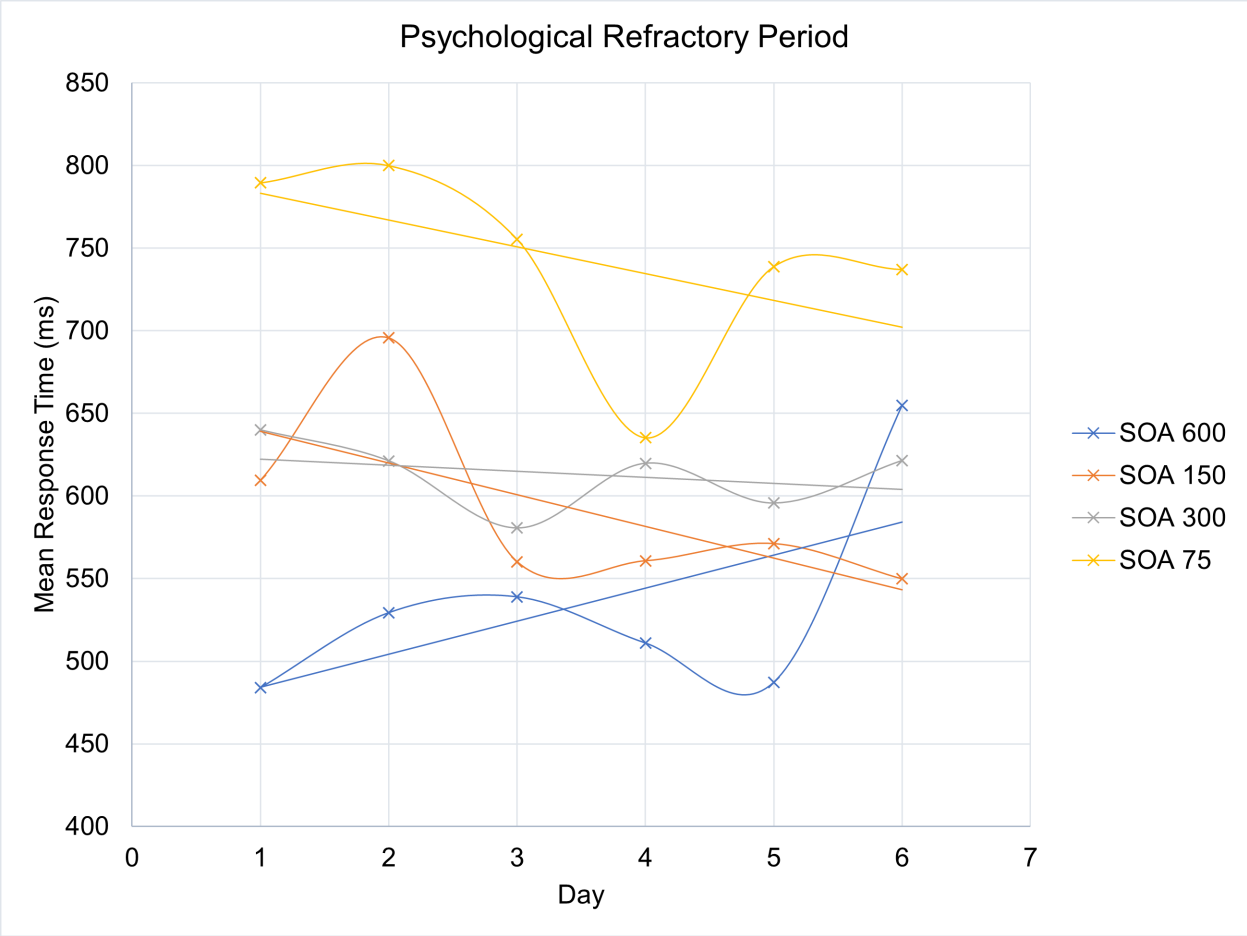
4.1 Cognitive Tests

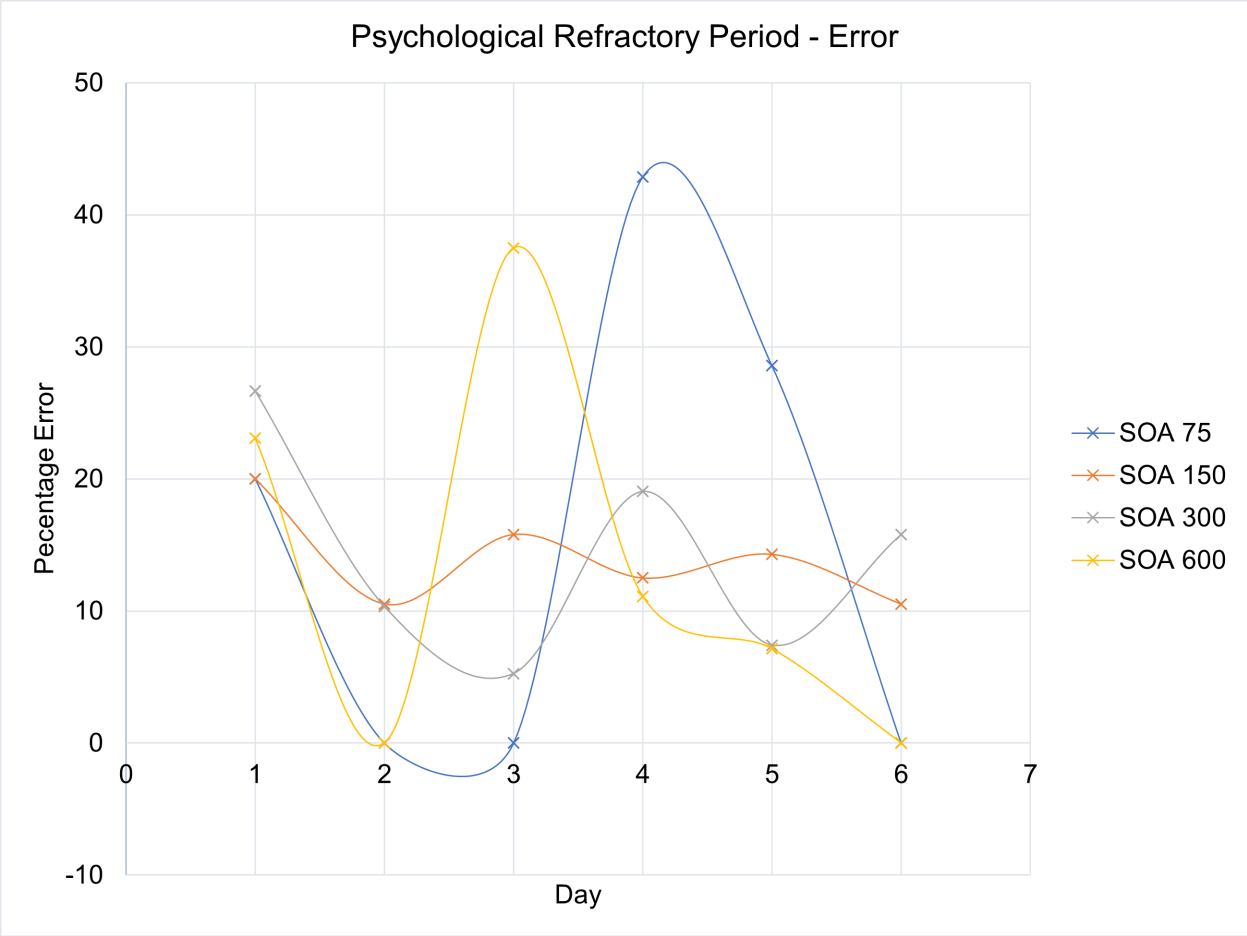
4.1.1 Period A - Baseline

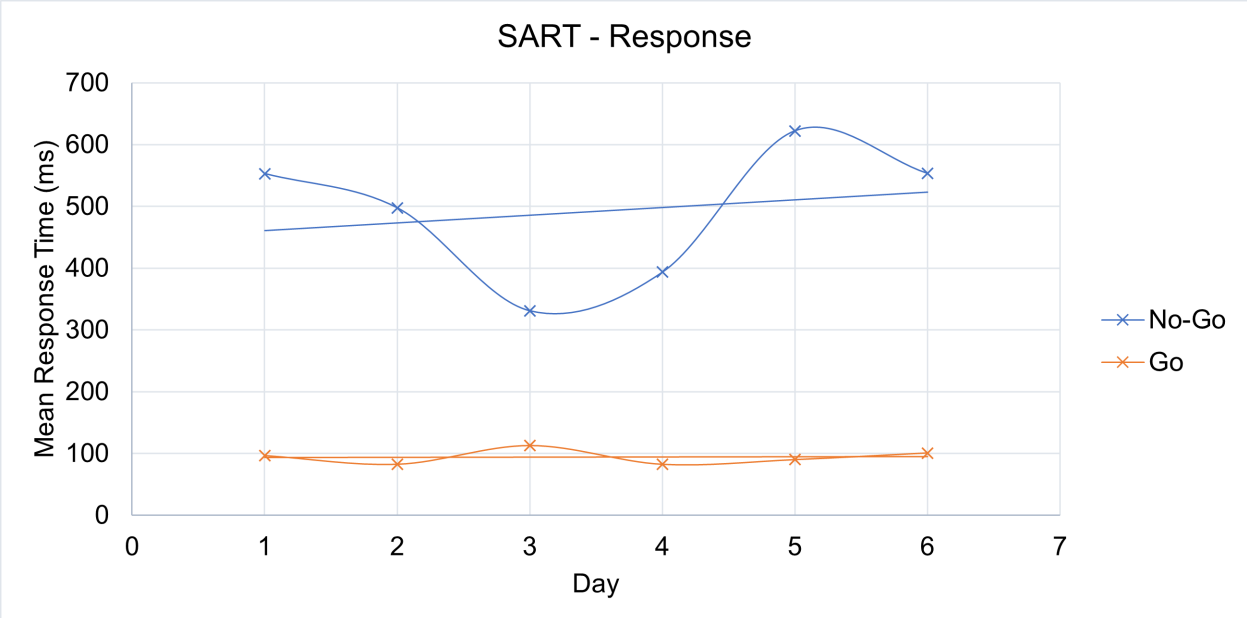


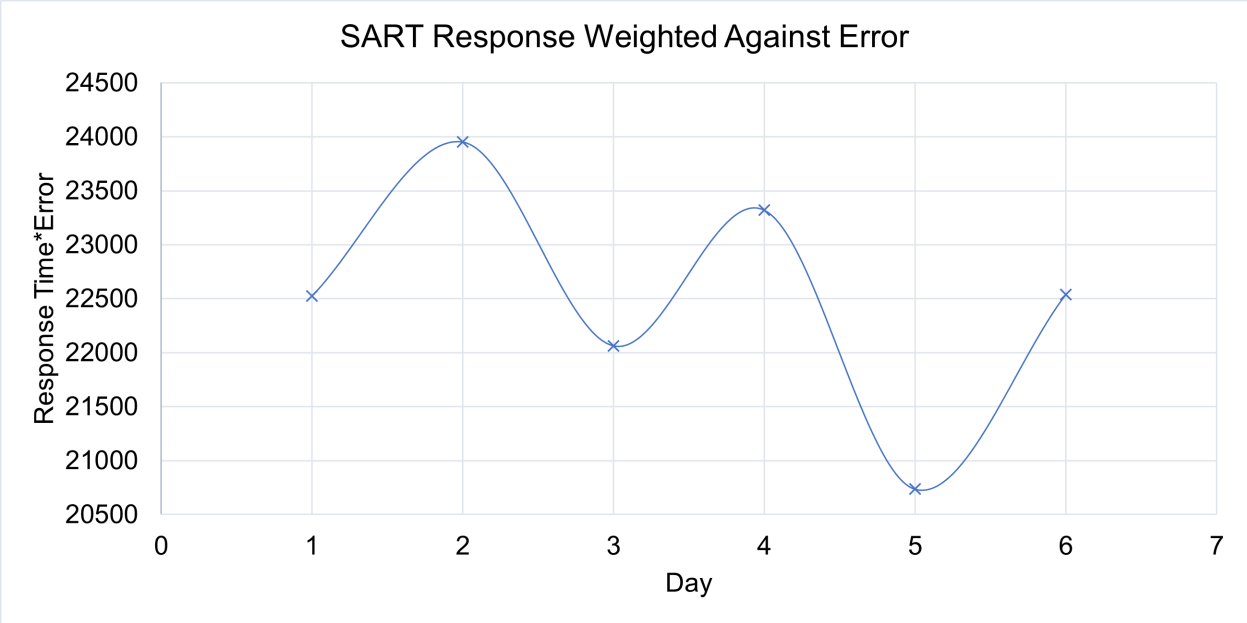

Eriskon Flanker
Mean Response Time (ms)
580
560
540
520
500
480
460
440
420
400
0
1
2
3
4
5
6
7
Day
Incongruent
Congruent

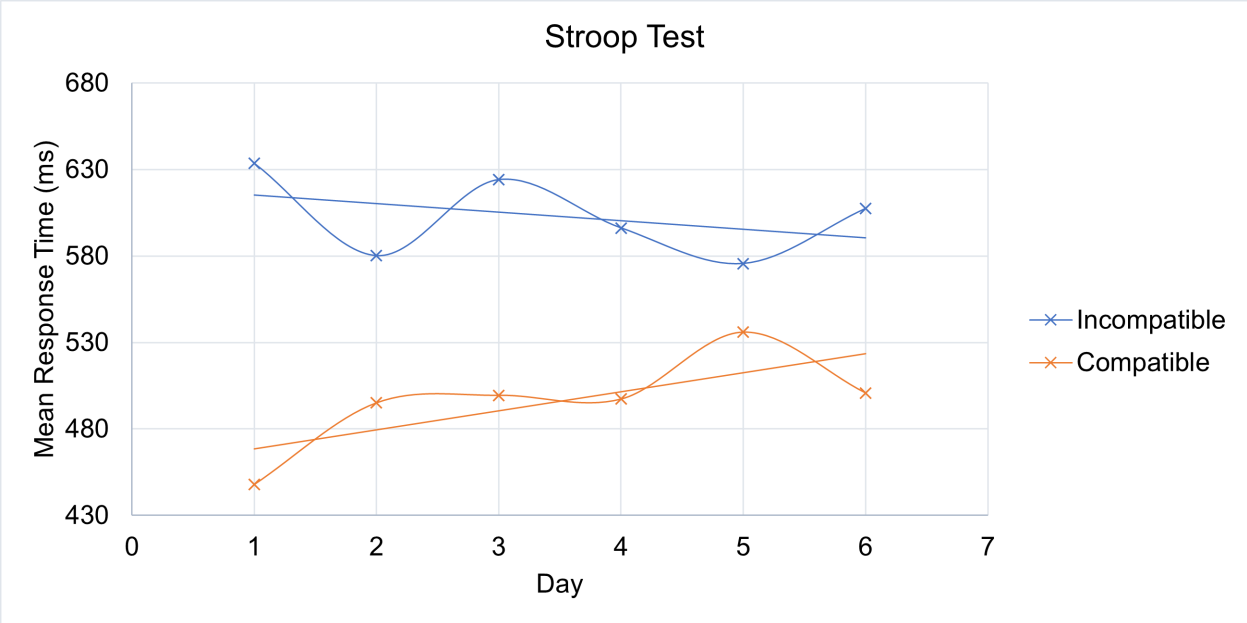

Posner Cueing
Mean Response Time (ms)
390
370
350
330
310
290
270
250
230
Day
Uncued
Cued

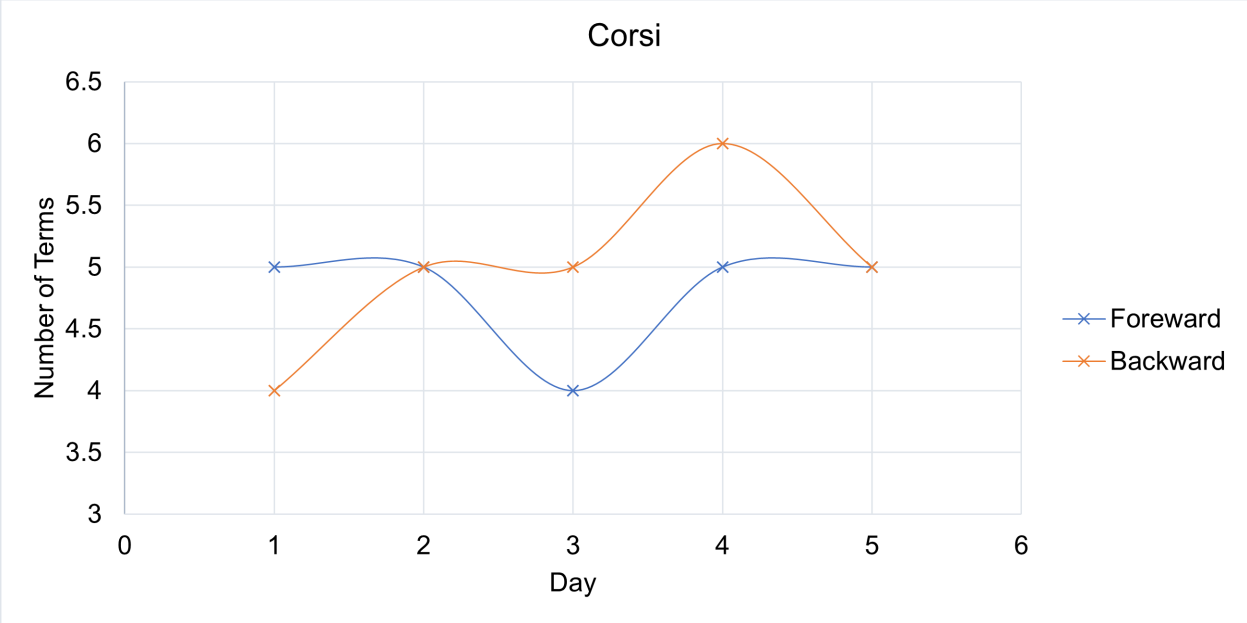

Psychological Refractory Period
Mean Response Time (ms)
850
800
750
700
650
600
550
500
450
400
0
1
2
3
4
5
6
7
Day
SOA 600
SOA 150
SOA 300
SOA 75

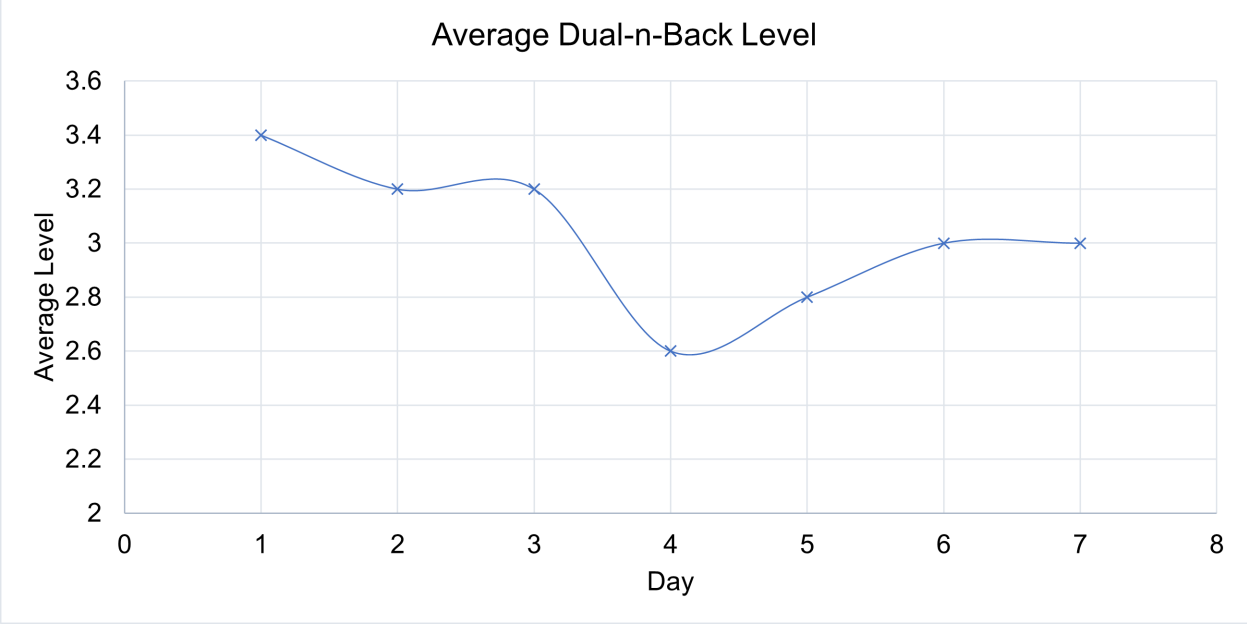

Psychological Refractory Period - Error
Pecentage Error
50
40
30
20
10
0
-10
0
1
2
3
4
5
6
7
Day
SOA 75
SOA 150
SOA 300
SOA 600

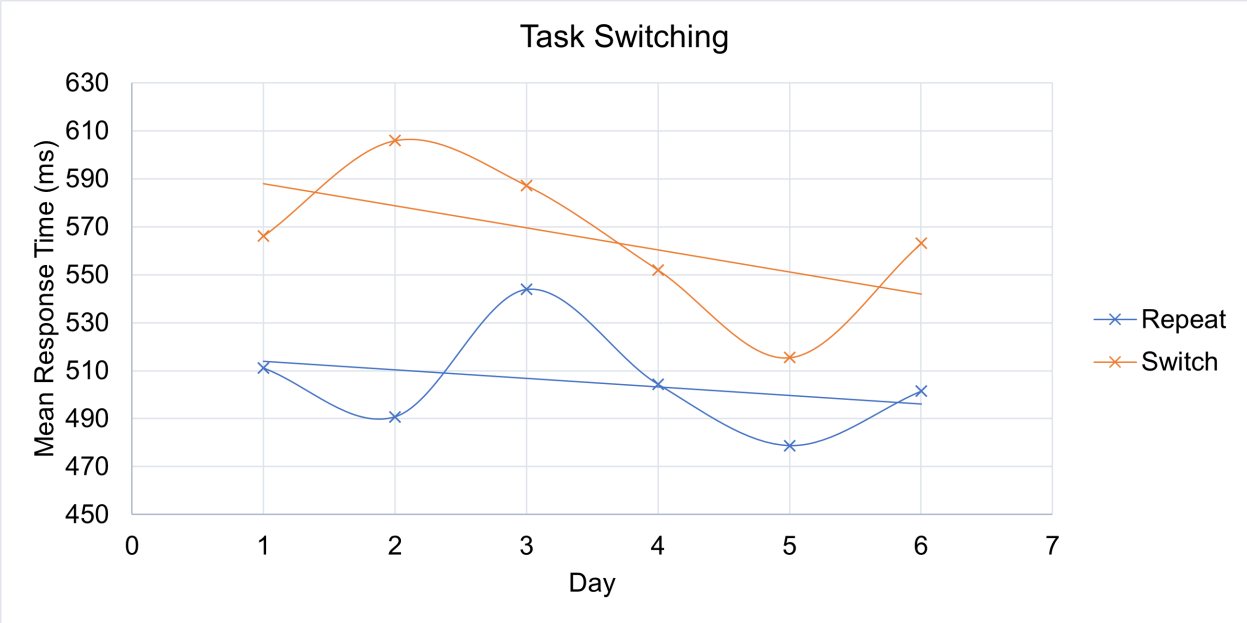

SART - Response
Mean Response Time (ms)
700
600
500
400
300
200
100
0
0
1
2
3
4
5
6
7
Day
No-Go
Go

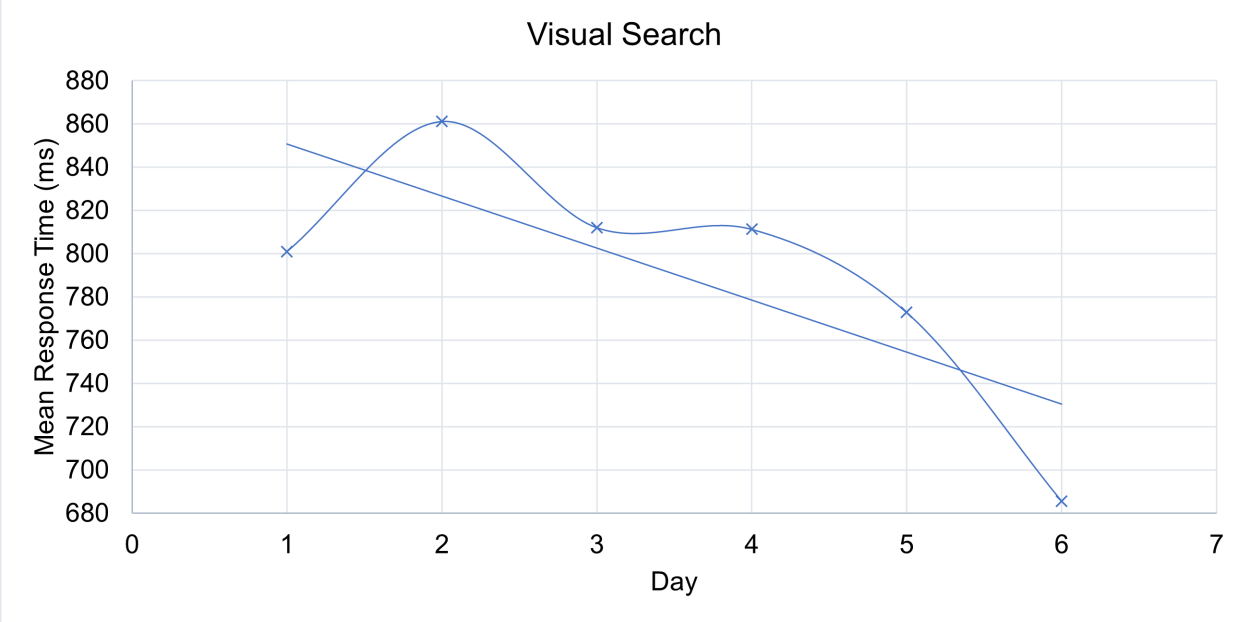

SART Response Weighted Against Error
Response Time*Error
24500
24000
23500
23000
22500
22000
21500
21000
20500
0
1
2
3
4
5
6
7
Day


Stroop Test
Mean Response Time (ms)
680
630
580
530
480
430
0
1
2
3
4
5
6
7
Day
Incompatible
Compatible


Corsi
Number of Terms
6.5
6
5.5
5
4.5
4
3.5
3
0
1
2
3
4
5
6
Day
Foreward
Backward


Average Dual-n-Back Level
Average Level
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
0
1
2
3
4
5
6
7
8
Day





Period A was originally designed to be nine days long, with a two day practice buffer however, due to work commitments this was reduced to eight days, and then further reduced to six days, with a four day practice period, after analysis of the data suggested that a longer practice period was required.

Regression analysis was undertaken to determine whether practice effects were small enough for the experiment to be analysable.

practice effects were deemed negligible if the calculated p value for the x-variable was found to be more than 0.1. If p was found to be less than 0.1 the test was deemed unfit as

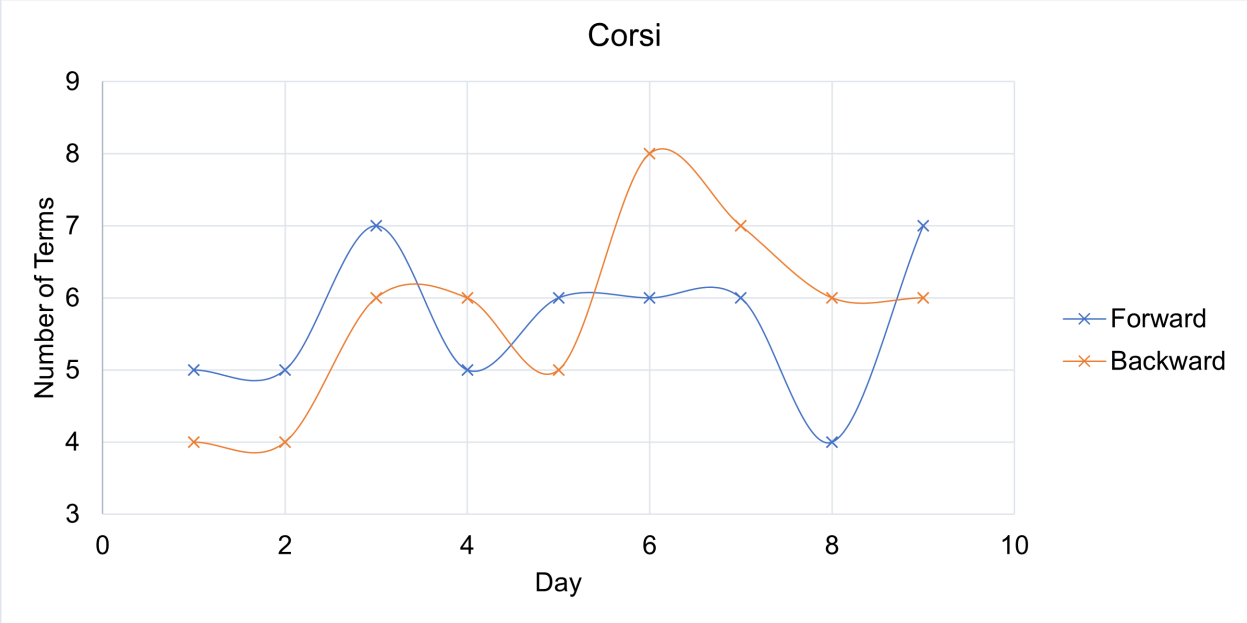
a good measure of change in cognitive performance and no conclusions would be made from its analysis. A p value of 0.05 is usually used in statistic analysis, however to reduce the chances of incorrect conclusions, from analysis of practice dependent tests, a higher p value was chosen.

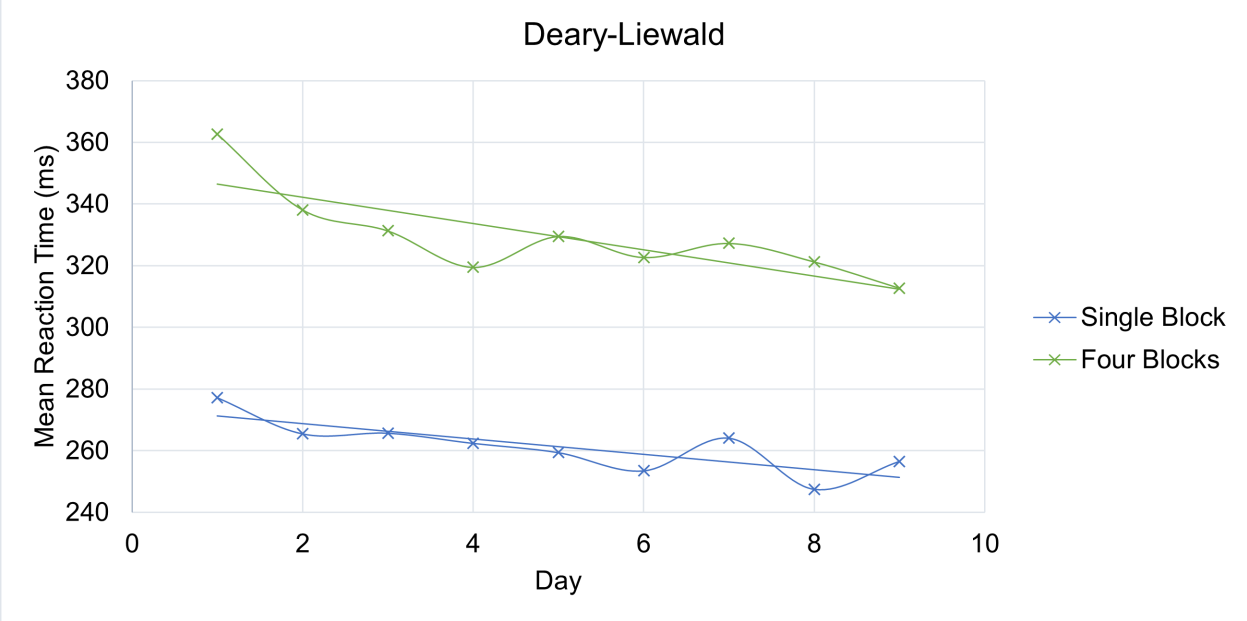
Task:	**p Value**
Deary-Liewald (single block)	0.158
Deary-Liewald (four blocks)	0.200
Visual Search	0.076
Task Switching (switch)	0.253
Task Switching (repeat)	0.565
Posner Cueing (cued)	0.363
Posner Cueing (uncued)	0.937
Stroop (compatible)	0.098
Stroop (Incompatible)	0.439
Eriksen-Flanker (incongruent)	0.009
Eriksen-Flanker (congruent)	0.243
SART (go)	0.908
SART (no-go)	0.684
PRP (SOA - 75)	0.214
PRP (SOA - 150)	0.162
PRP (SOA - 300)	0.528
PRP (SOA - 600)	0.296
Average Dual-n-Back	0.536

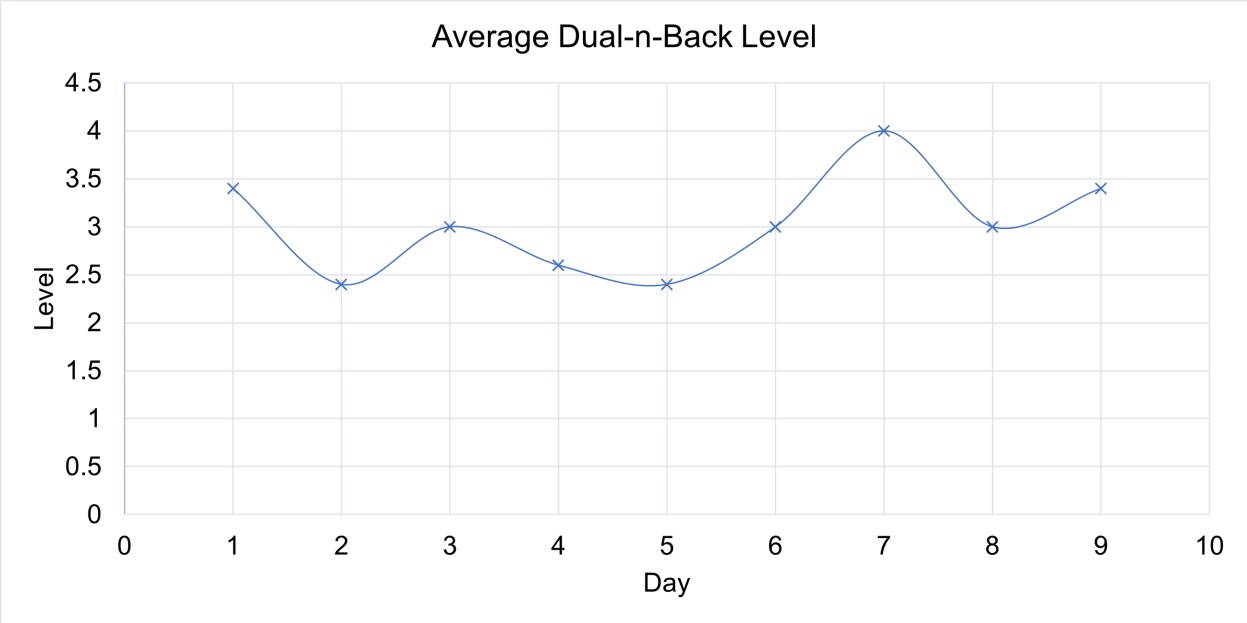
Therefore, Visual Search, Stroop (compatible) and Eriksen-Flanker (incongruent) were not used as measures of cognitive performance. Visual search due to its great magnitude of practice effect (-25ms/day) was abandoned early on in the experiment.

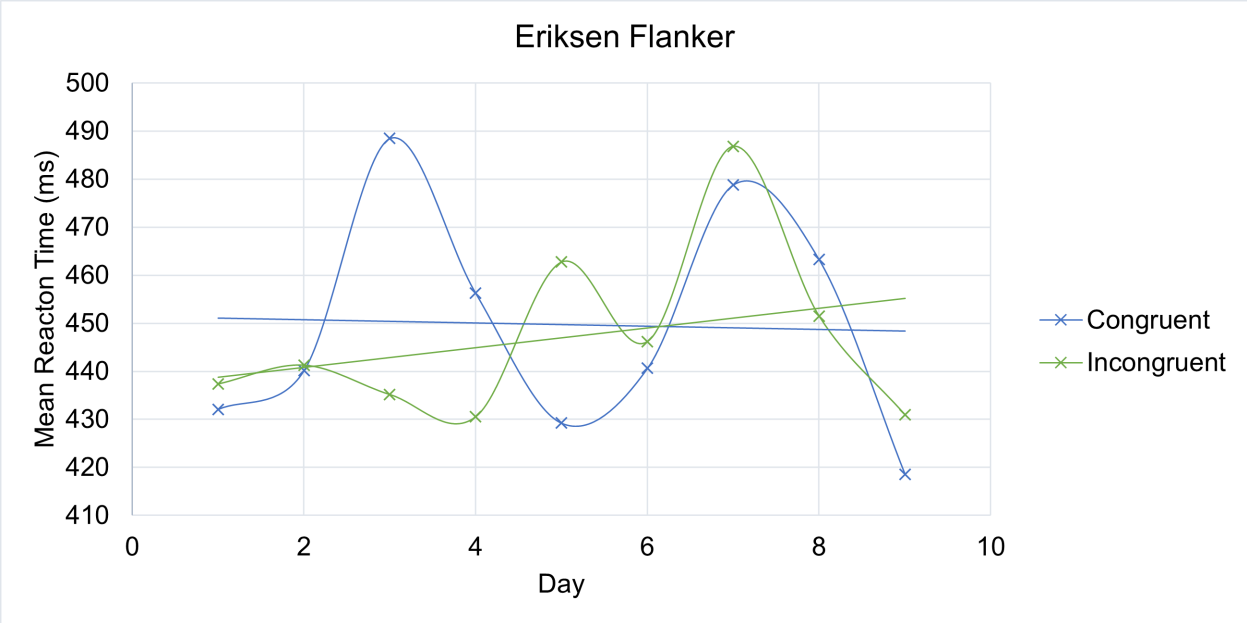
The magnitude of practice effects for Stroop (compatible) and Eriksen-Flanker (incongruent) were found to be +11ms/day and -19ms/day respectively.

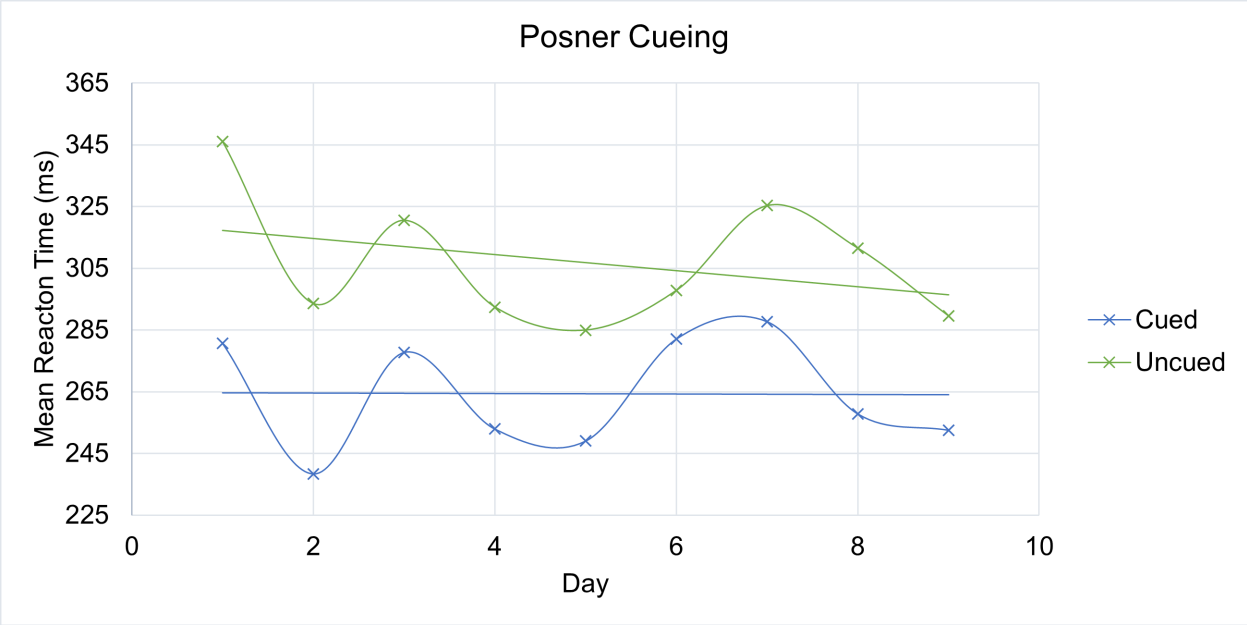
4.1.2 Period B*

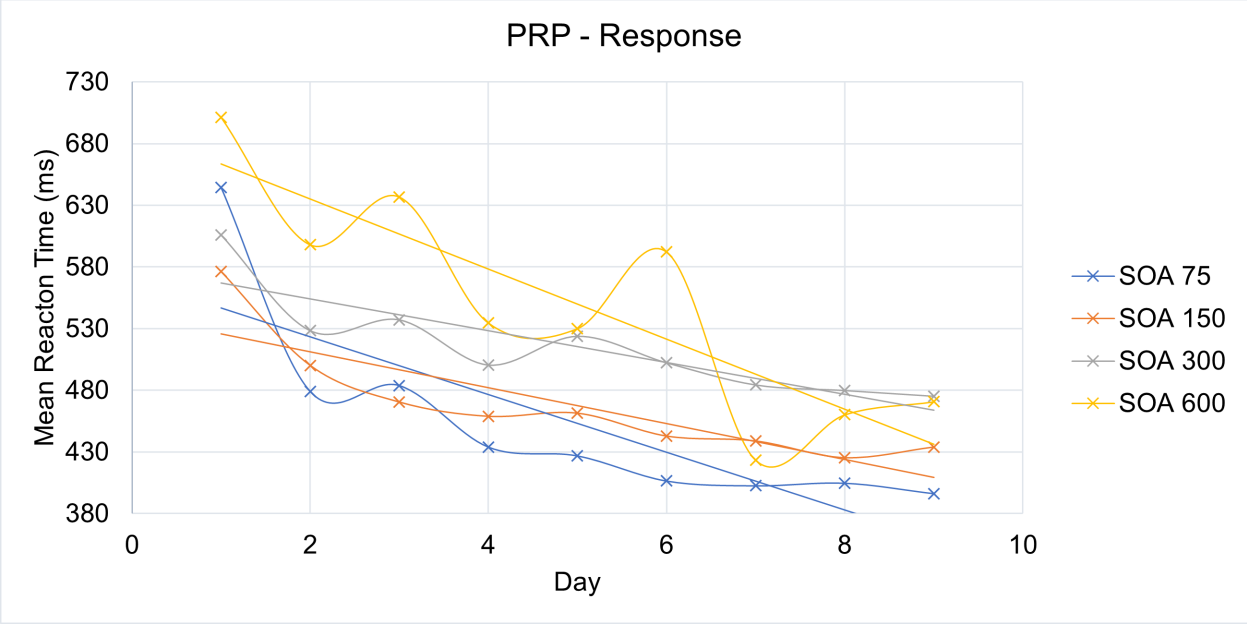

Corsi
Number of Terms
9
8
7
6
5
4
3
0
2
4
6
8
10
Day
Forward
Backward

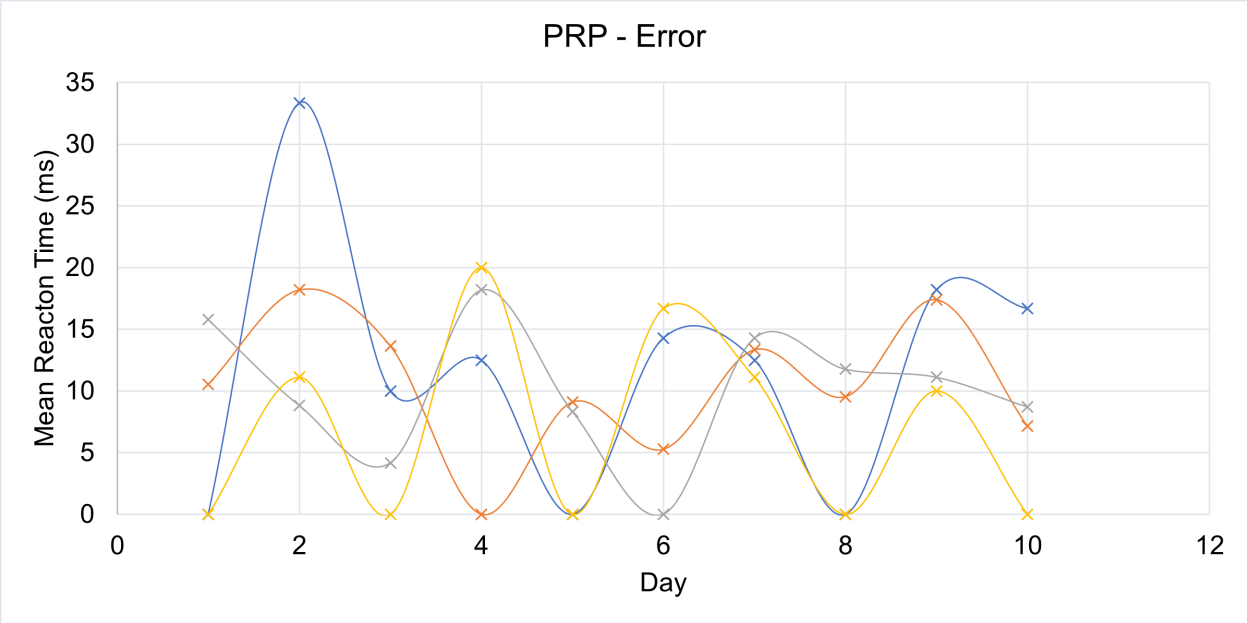

Deary-Liewald
Mean Reaction Time (ms)
380
360
340
320
300
280
260
240
0
2
4
6
8
10
Day
Single Block
Four Blocks

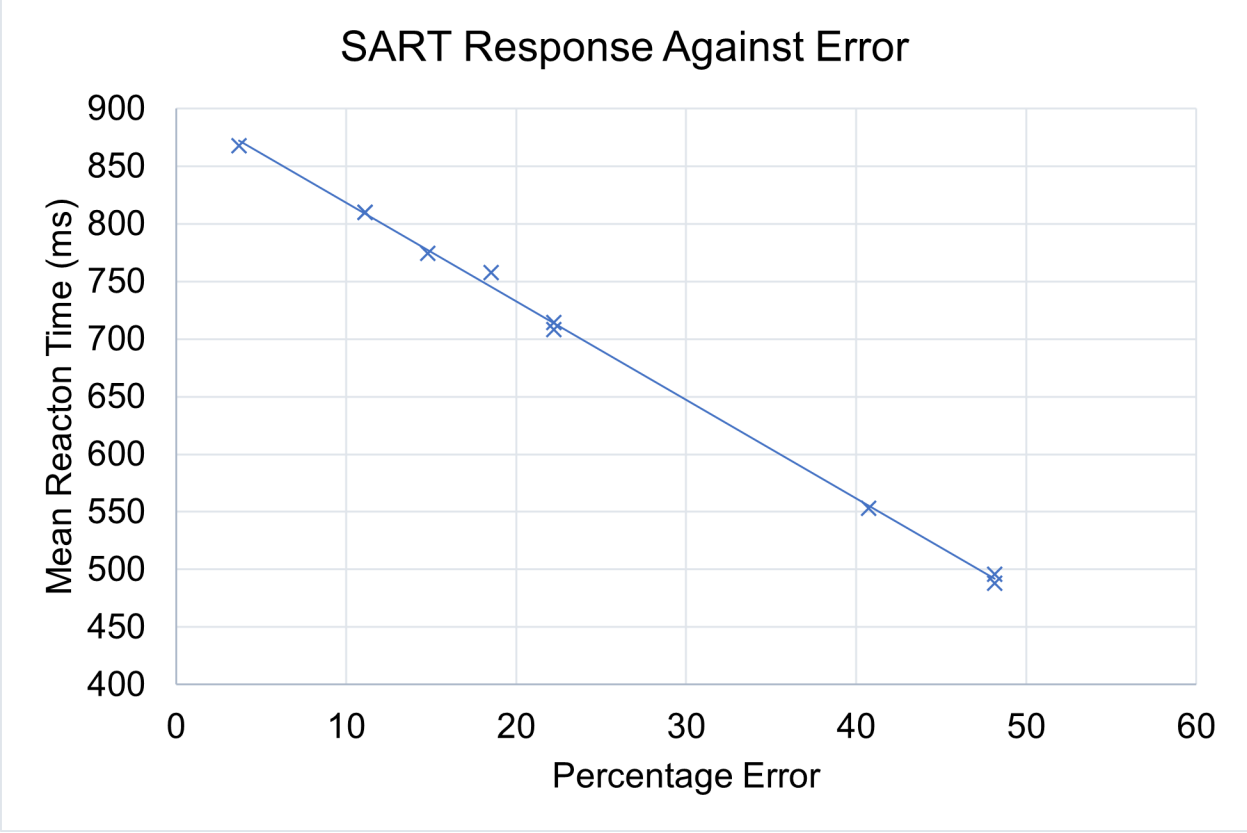

Average Dual-n-Back Level
Level
Day
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0
1
2
3
4
5
6
7
8
9
10

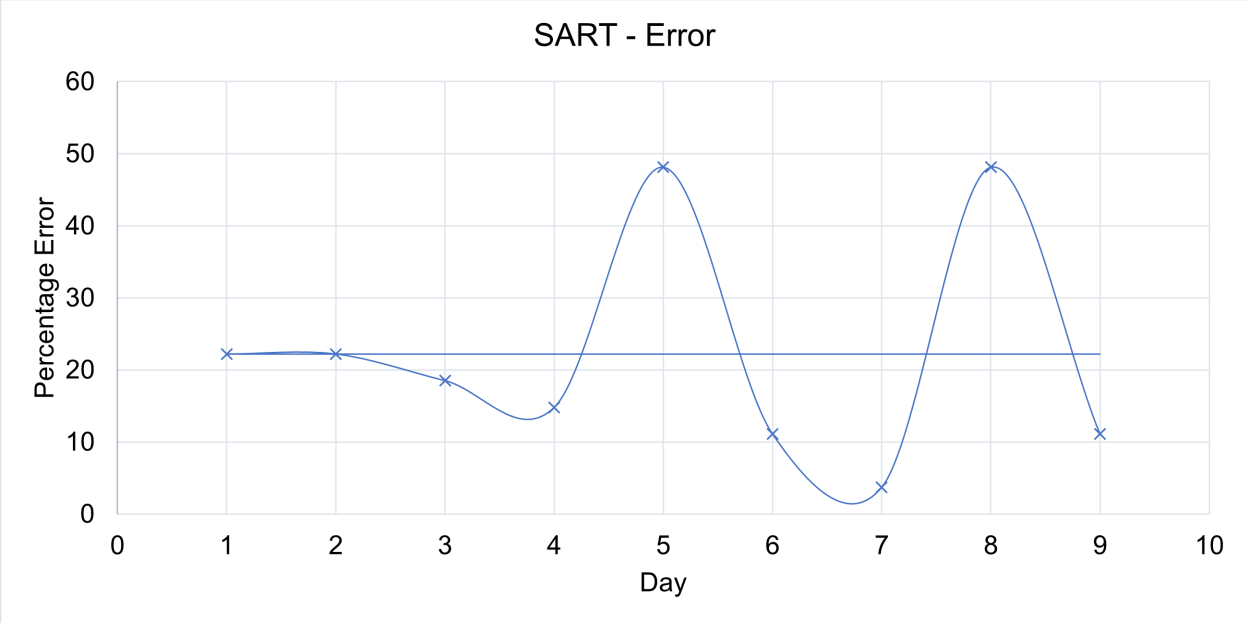

Eriksen Flanker
Mean Reacton Time (ms)
Day
500
490
480
470
460
450
440
430
420
410
0
2
4
6
8
10
Congruent
Incongruent

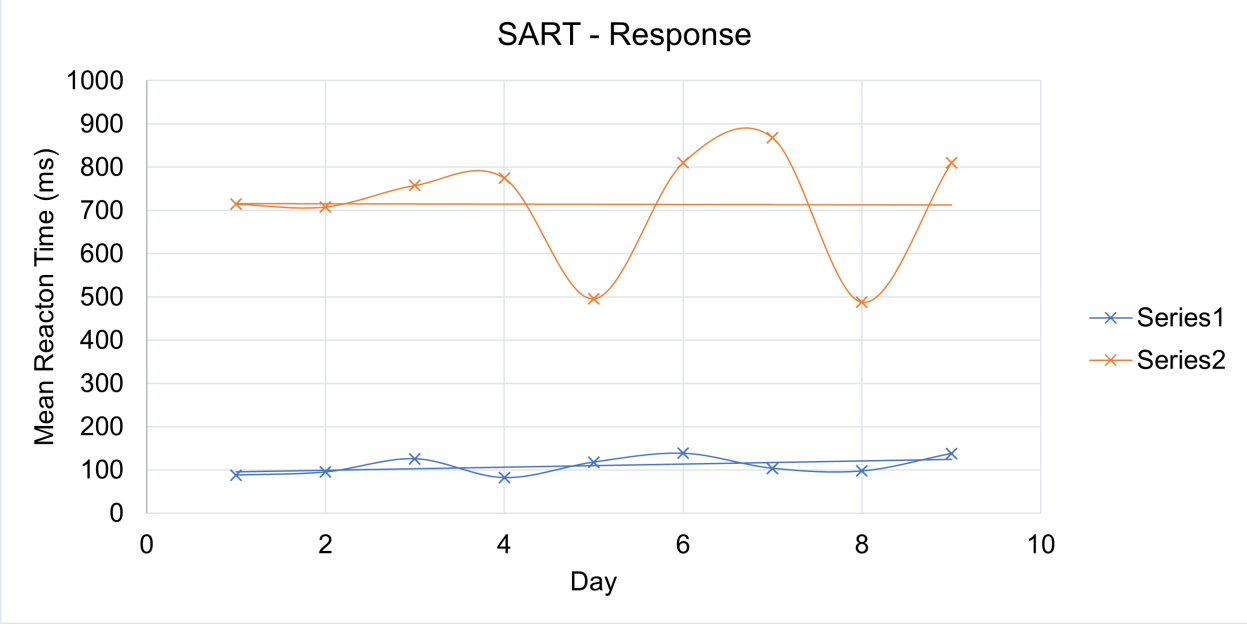

Posner Cueing
Mean Reacton Time (ms)
365
345
325
305
285
265
245
225
0
2
4
6
8
10
Day
Cued
Uncued

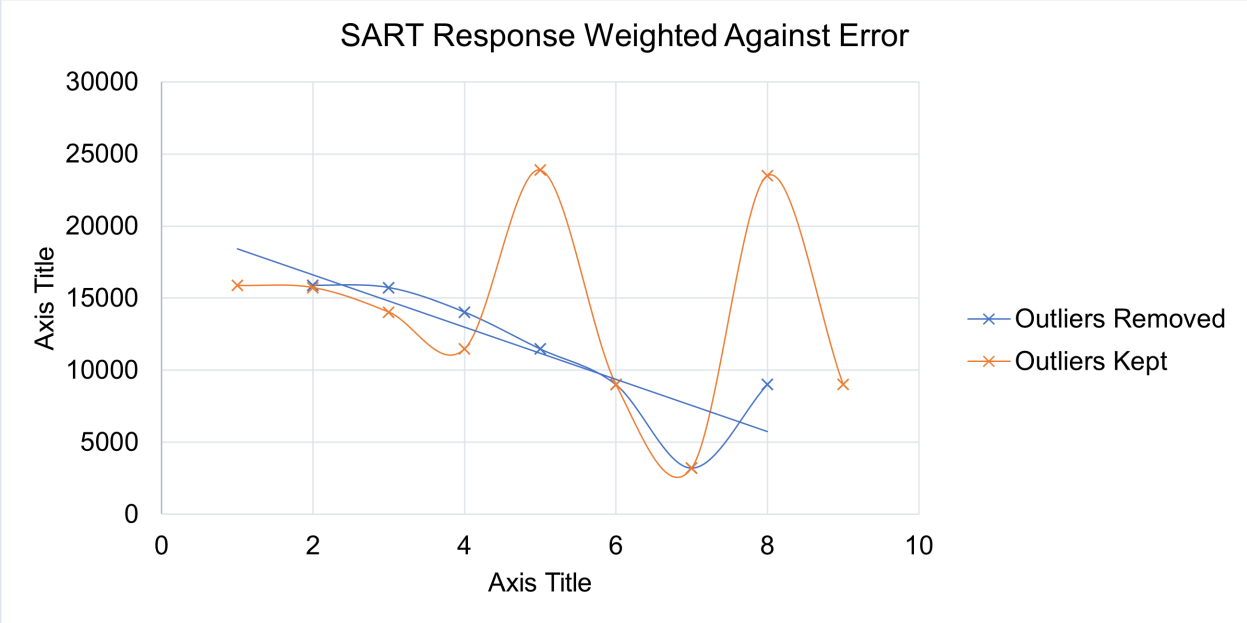

PRP - Response
Mean Reacton Time (ms)
730
680
630
580
530
480
430
380
0
2
4
6
8
10
Day
SOA 75
SOA 150
SOA 300
SOA 600

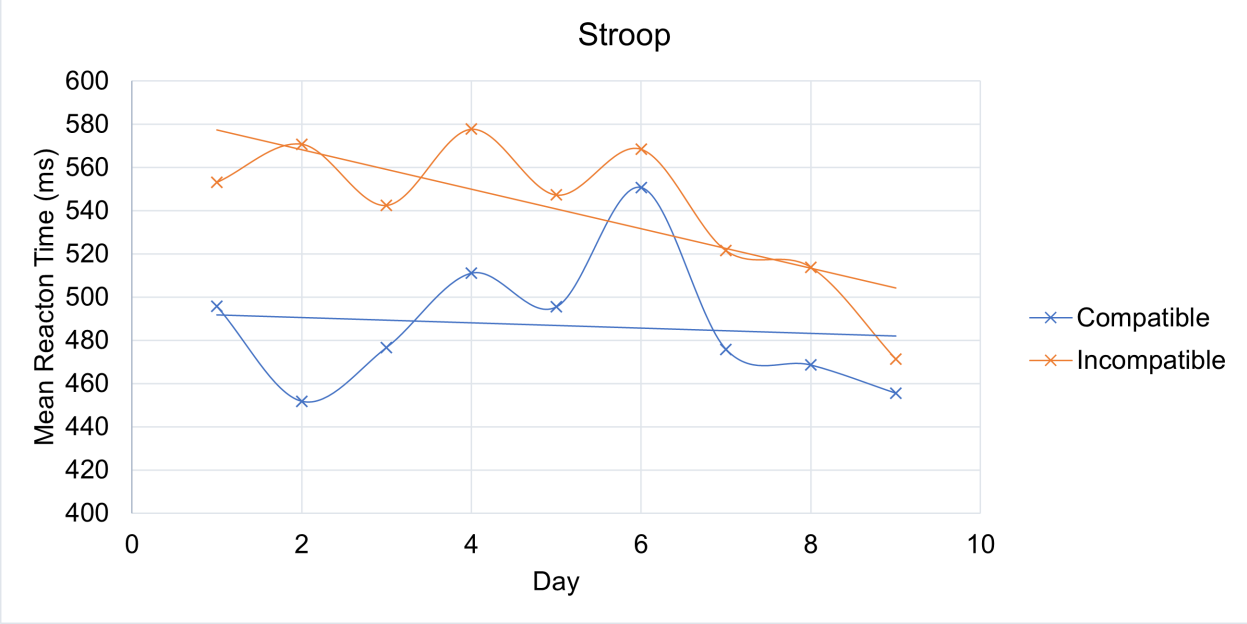

PRP - Error
Mean Reacton Time (ms)
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
Day

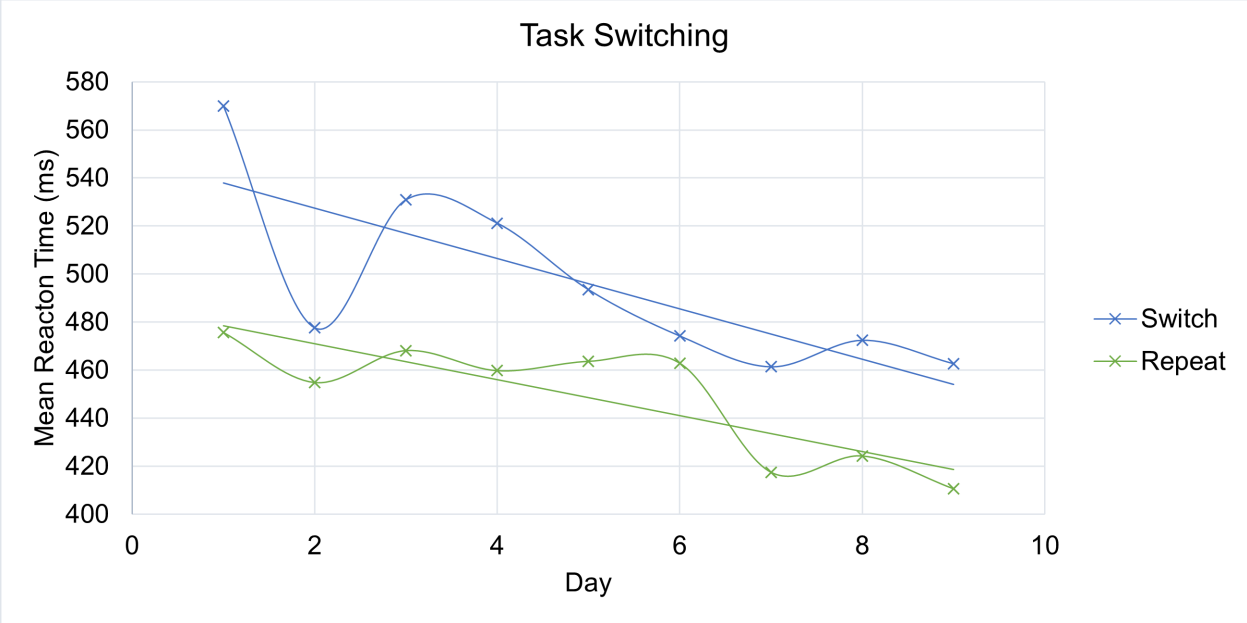

SART Response Against Error
Mean Reacton Time (ms)
900
850
800
750
700
650
600
550
500
450
400
0
10
20
30
40
50
60
Percentage Error


SART - Error
Percentage Error
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
Day


SART - Response
Mean Reacton Time (ms)
1000
900
800
700
600
500
400
300
200
100
0
0
2
4
6
8
10
Day
Series1
Series2


SART Response Weighted Against Error
30000
25000
20000
15000
10000
5000
0
Axis Title
0
2
4
6
8
10
Axis Title
Outliers Removed
Outliers Kept


Stroop
600
580
560
540
520
500
480
460
440
420
400
Mean Reacton Time (ms)
0
2
4
6
8
10
Day
Compatible
Incompatible



A simple sign test, using the average value from our baseline measurements as reference, was undertaken to determine whether Ashwagandha has any effect on cognitive performance.

Regression was also performed on the data, so as to highlight the magnitude and rate of improvement (if any was found).

Due to work commitments period B* was also reduced to nine days.

Table 1: Regression Analysis Results. Rows in red indicate those tests that had a statistically significant practice effect associated with them.

Task:	**X-Variable:**	**p Value**
Deary-Liewald (single block)	-2.48	0.010
Deary-Liewald (four blocks)	-4.25	0.009
Task Switching (switch)	-10.50	0.014
Task Switching (repeat)	-7.49	0.004
Posner Cueing (cued)	-0.09	0.973
Posner Cueing (uncued)	-2.62	0.353
Stroop (compatible)	-1.21	0.783
Stroop (Incompatible)	-9.15	0.022
Eriksen-Flanker (incongruent)	2.06	0.416
Eriksen-Flanker (congruent)	-0.33	0.922
SART (go)	3.65	0.199
SART (no-go)	-0.36	0.985
PRP (SOA - 75)	-23.43	0.007
PRP (SOA - 150)	-14.55	0.003
PRP (SOA - 300)	-12.89	0.002
PRP (SOA - 600)	-28.42	0.003
Average Dual-n-Back	0.07	0.333

Regression analysis performed for SART (no-go) weighted against its error, with two outliers removed resulted in a p-value of 0.0129 - a significant result.

Table 2: Sign Test results. Rows in red indicate those tasks in which the sign test came out as FALSE - do not reject the null hypothesis (ie that the baseline and period B* data are of the same distribution).

Task:	**Sign Test Result:**
Deary-Liewald (single block)	TRUE
Deary-Liewald (four blocks)	TRUE
Task Switching (switch)	TRUE
Task Switching (repeat)	TRUE
Posner Cueing (cued)	TRUE
Posner Cueing (uncued)	TRUE
Stroop (compatible)	FALSE
Stroop (Incompatible)	TRUE
Eriksen-Flanker (incongruent)	TRUE
Eriksen-Flanker (congruent)	TRUE
SART (go)	FALSE
SART (no-go)	TRUE
PRP (SOA - 75)	TRUE
PRP (SOA - 150)	TRUE
PRP (SOA - 300)	TRUE
PRP (SOA - 600)	TRUE
Average Dual-n-Back	FALSE
Corsi Forward	FALSE
Corsi Backward	FALSE

4.1.3 Period B

To determine whether Ashwaghnda has any significant effect on cognitive performance both an unpaired t-test and Bayesian analysis were performed on the data set.

Bayesian analysis is used as an alternative to t-tests, producing posterior estimates for group means and standard deviations and their differences and effect sizes. [25]

Again due to work commitments period B was reduced to six days.

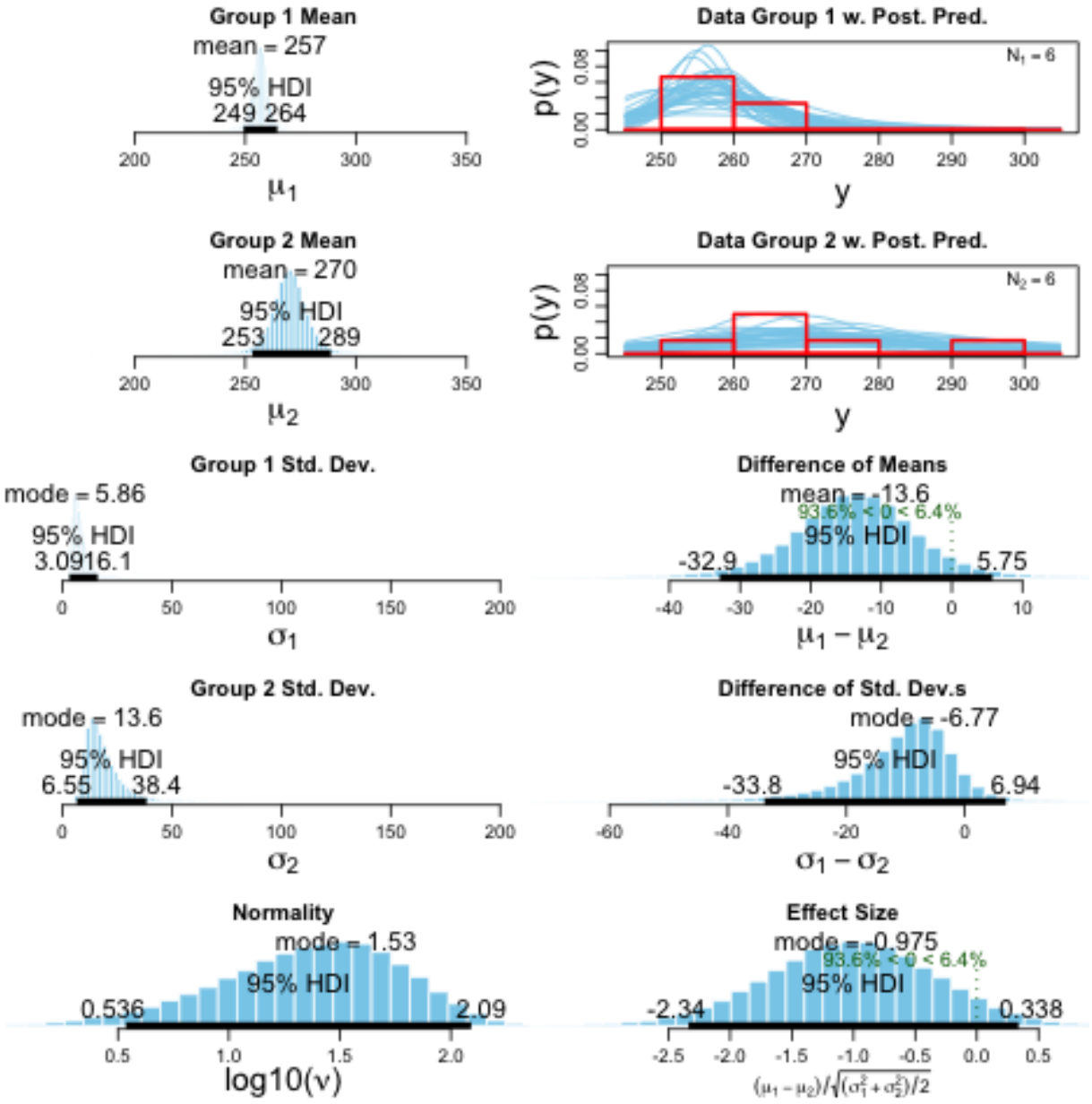


Figure 3: Deary-Liewald (single block)

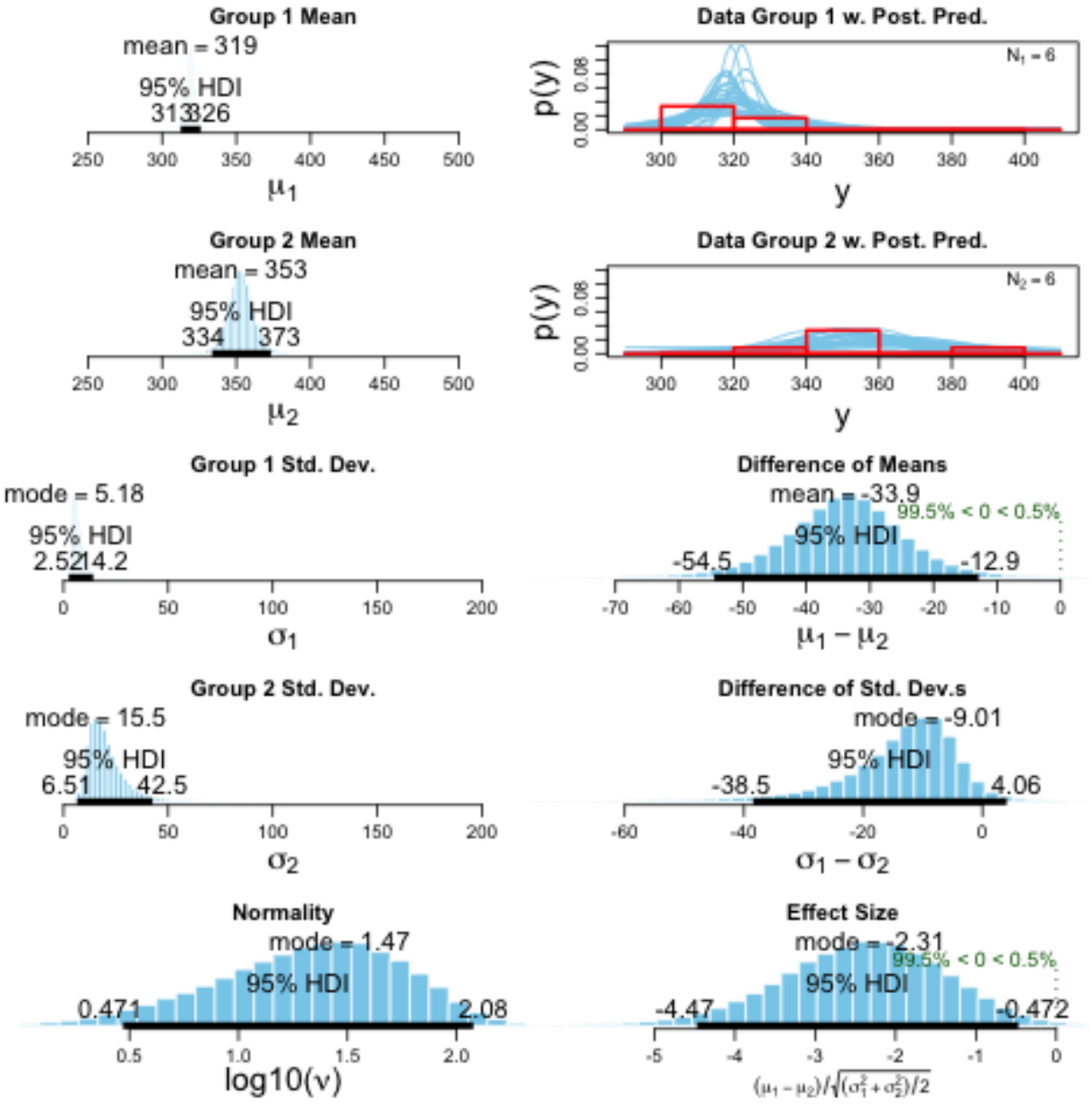


Figure 4: Deary-Liewald (four blocks)

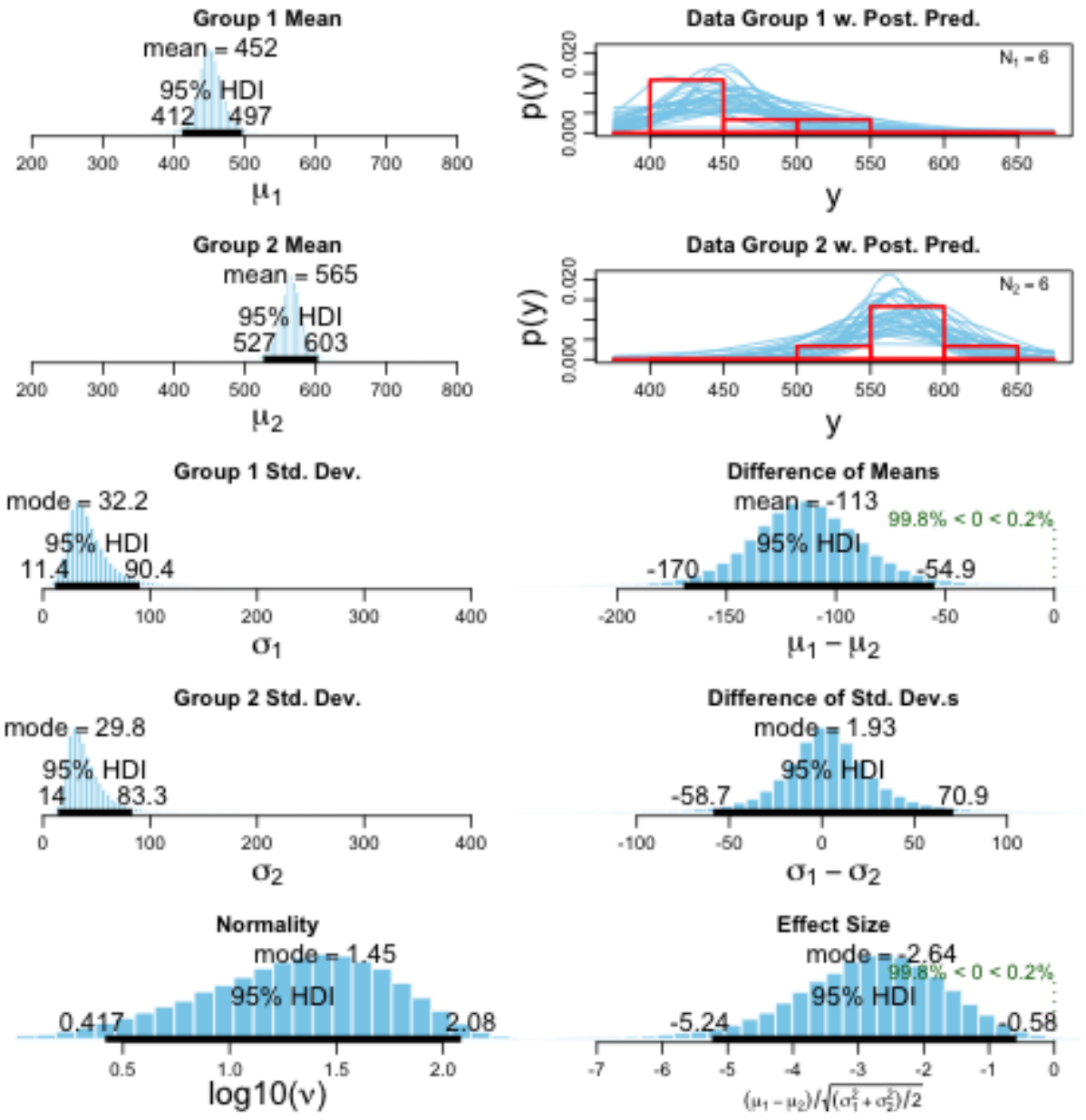


Figure 5: Task Switching (switch)

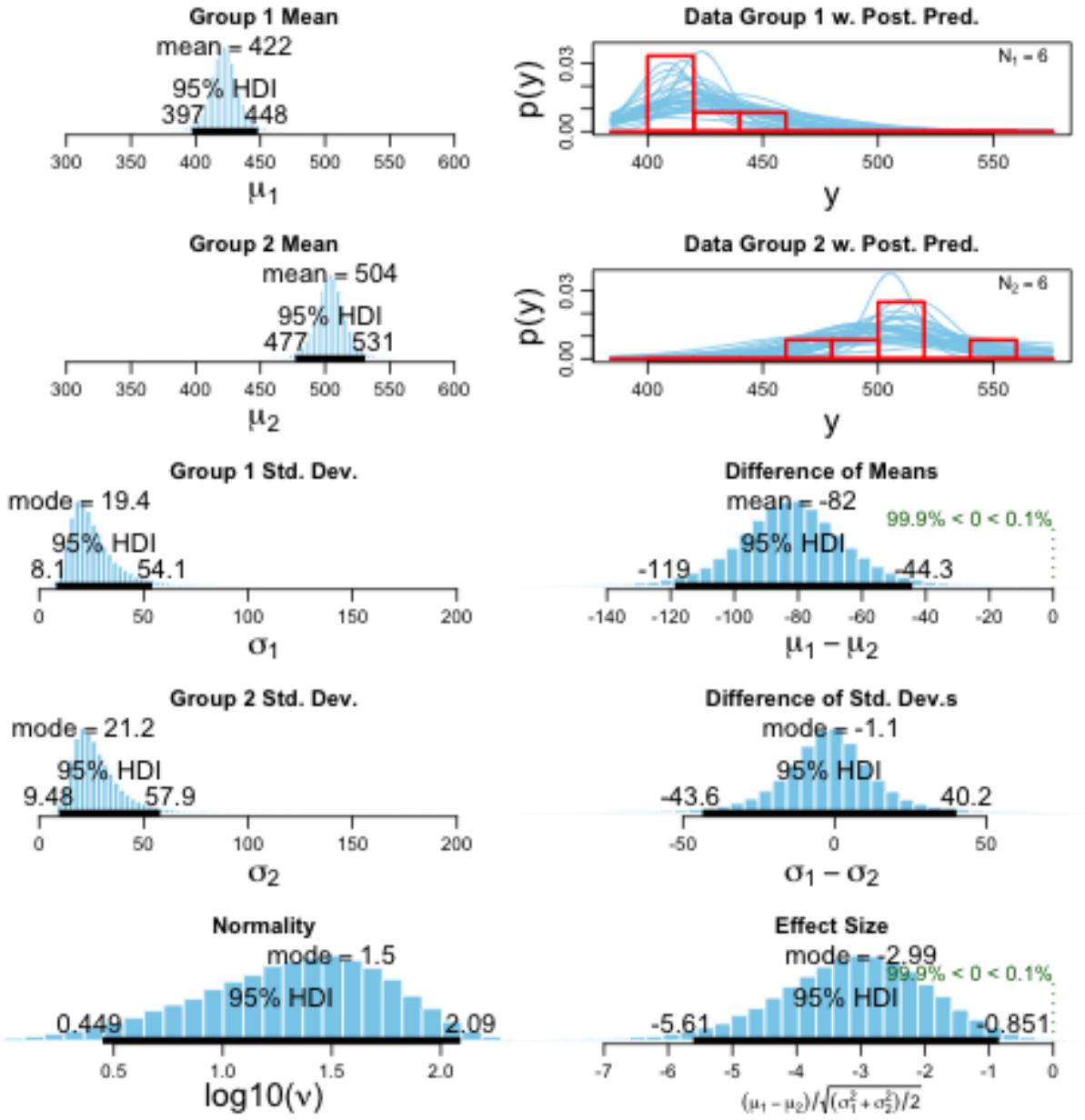


Figure 6: Task Switching (repeat)

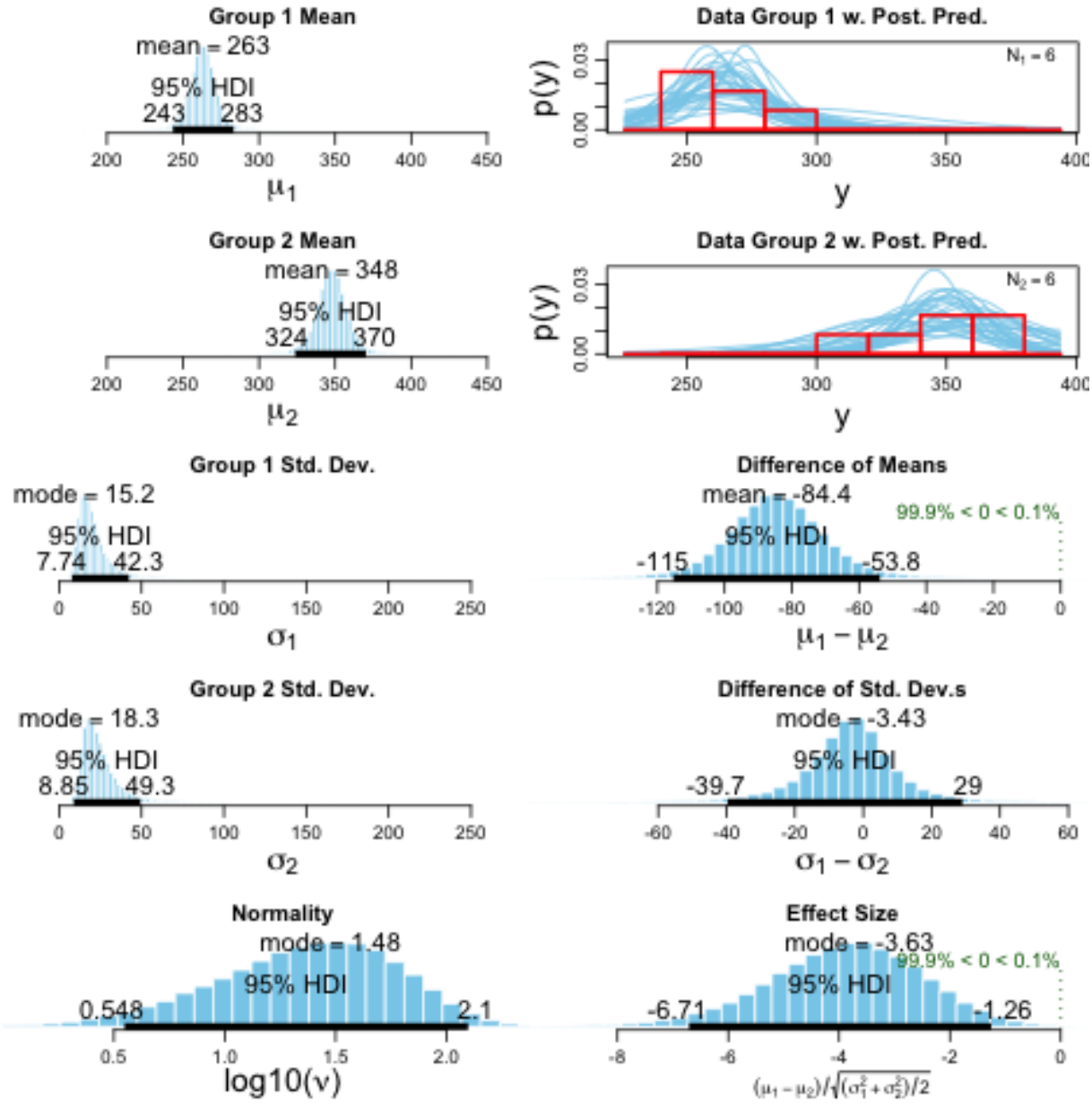


Figure 7: Posner Cueing (cued)

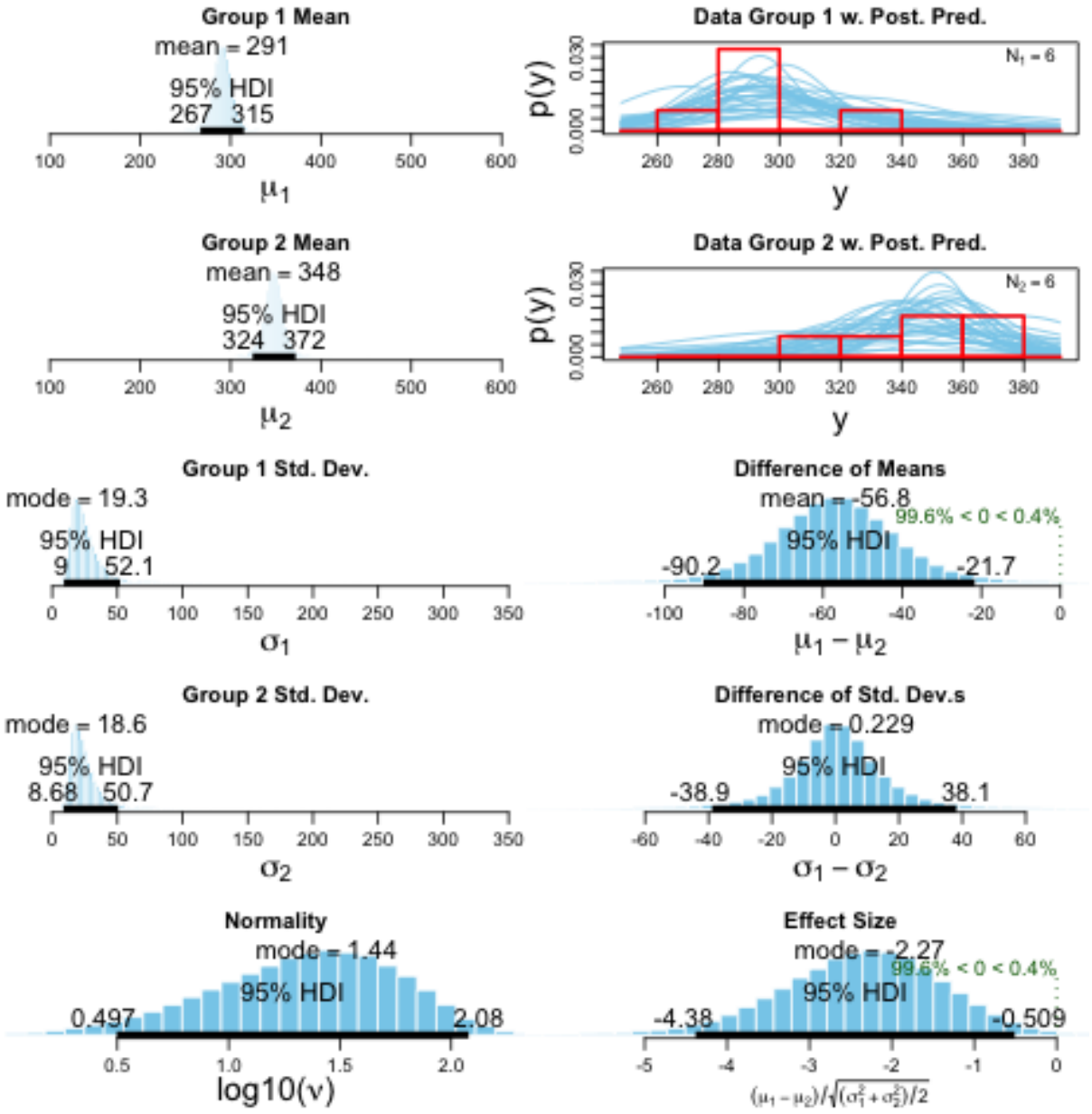


Figure 8: Posner Cueing (uncued)

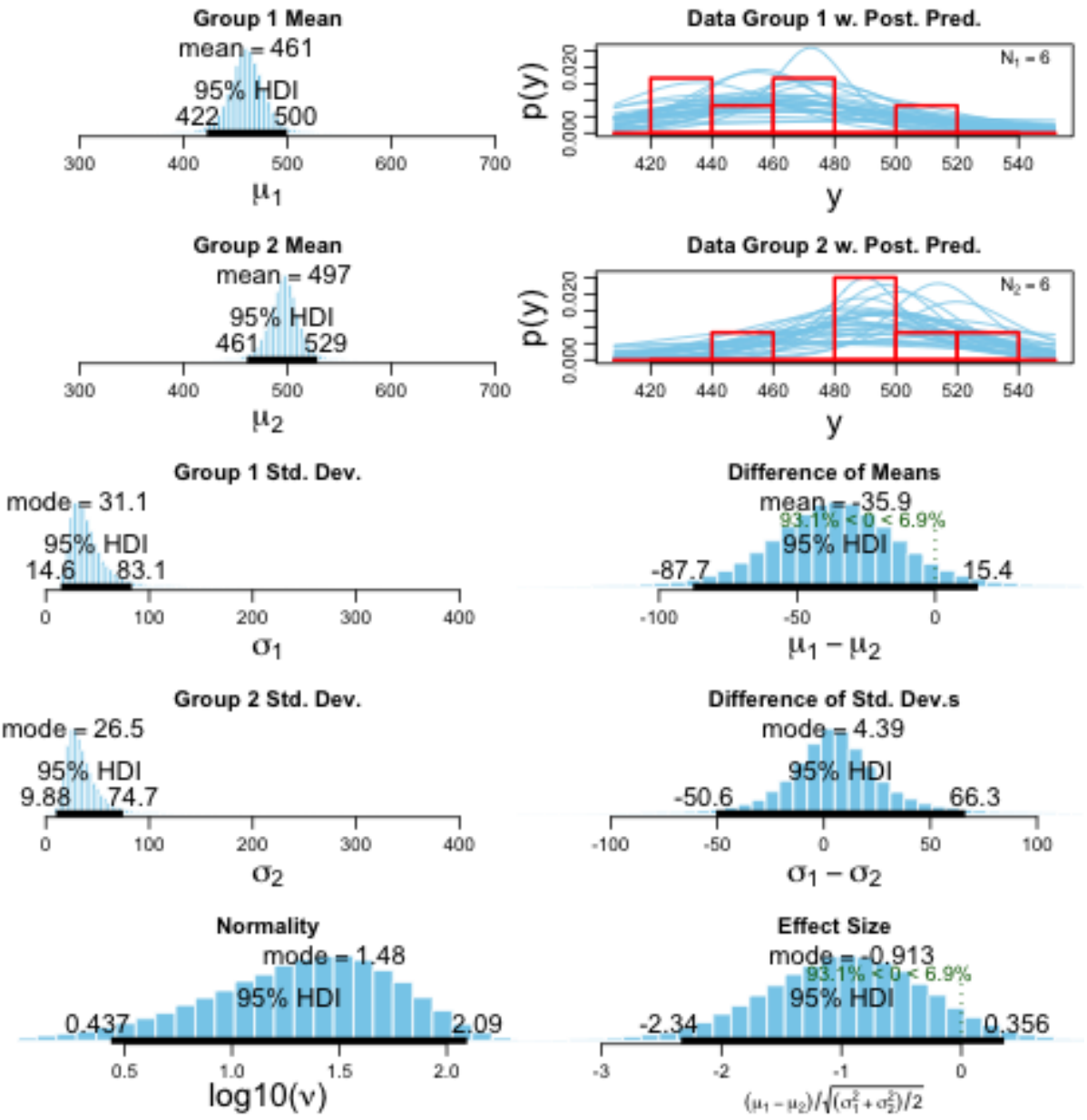


Figure 9: Stroop (compatible)

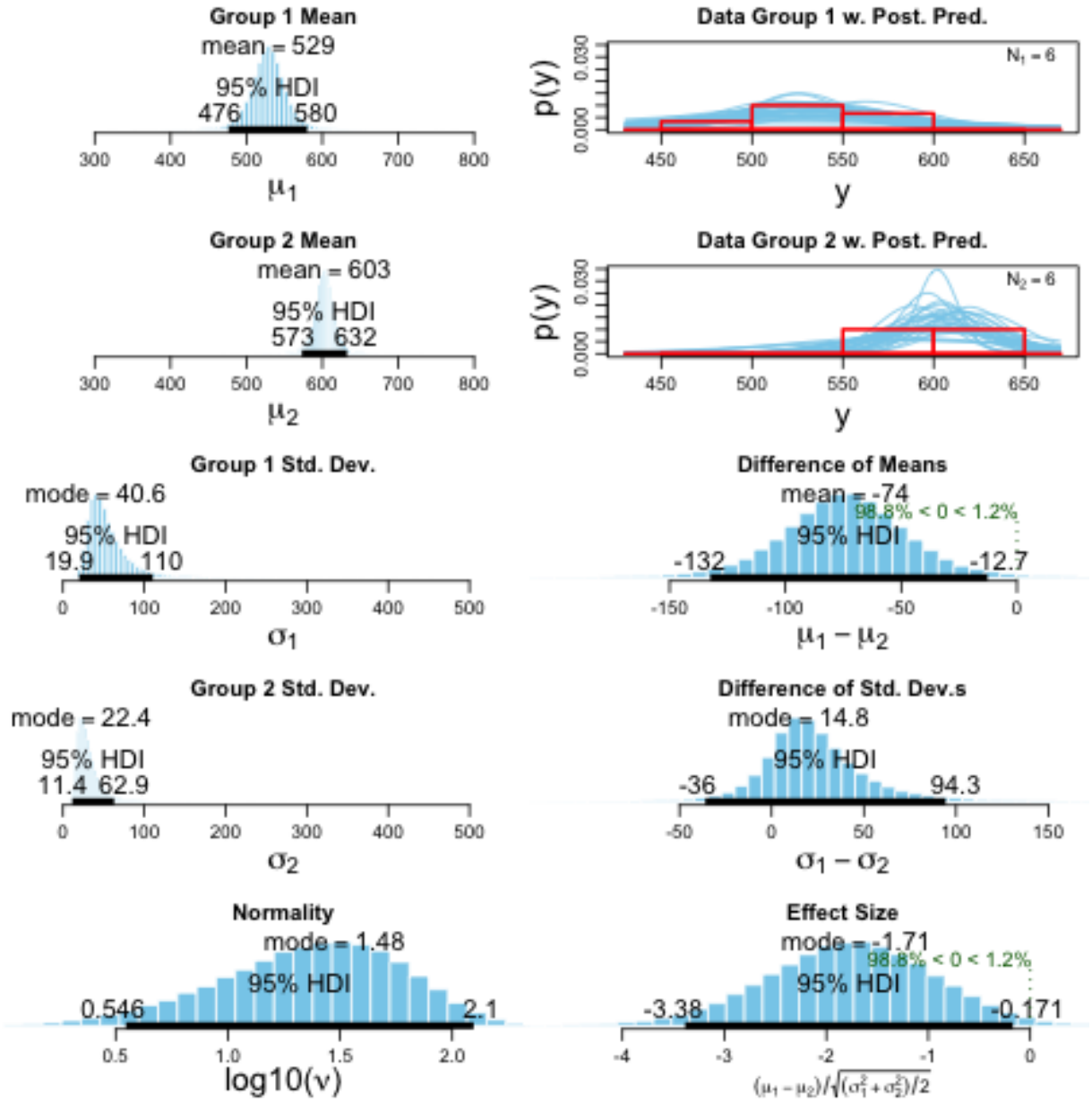


Figure 10: Stroop (incompatible)

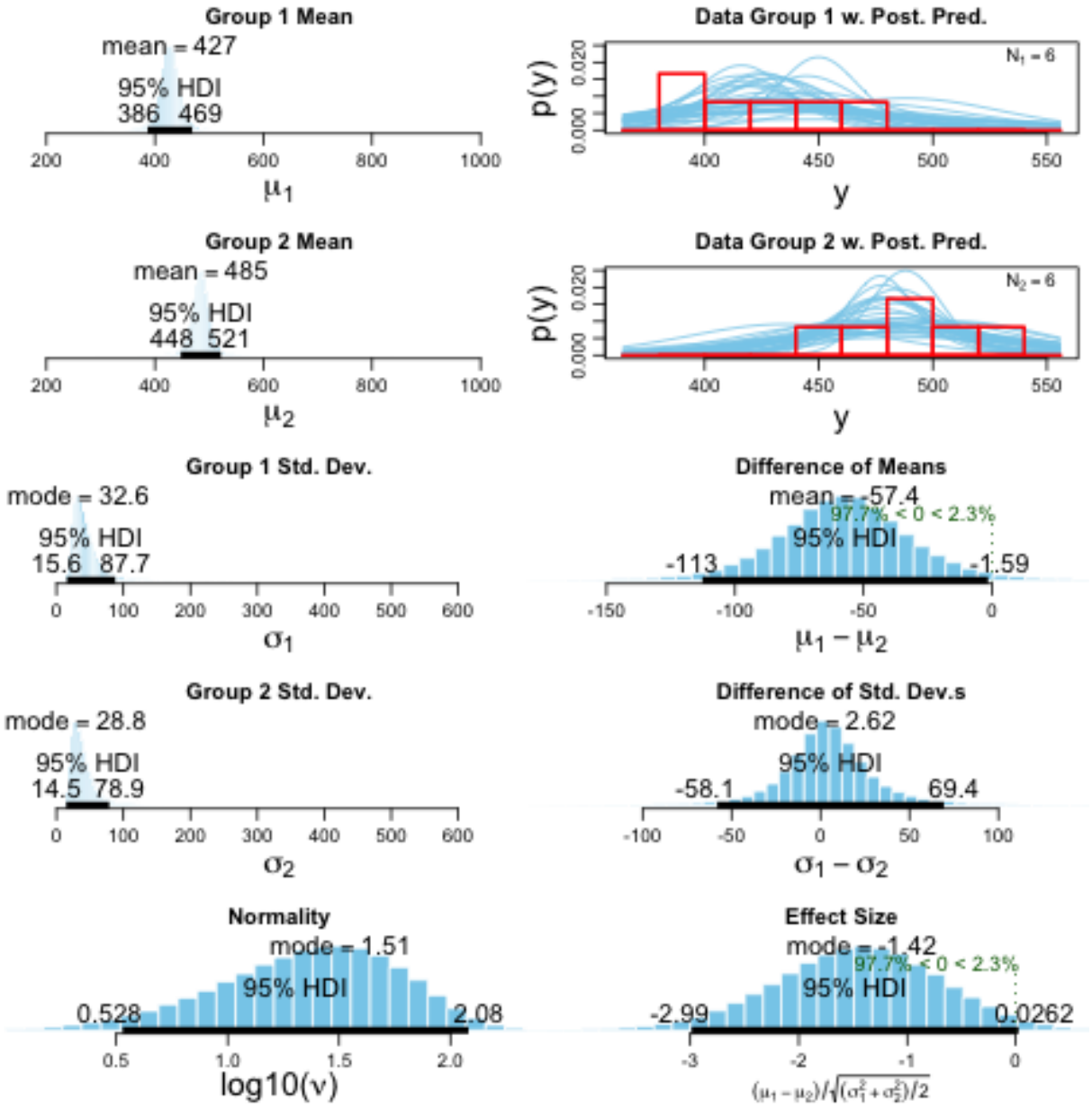


Figure 11: Eriksen-Flanker (congruent)

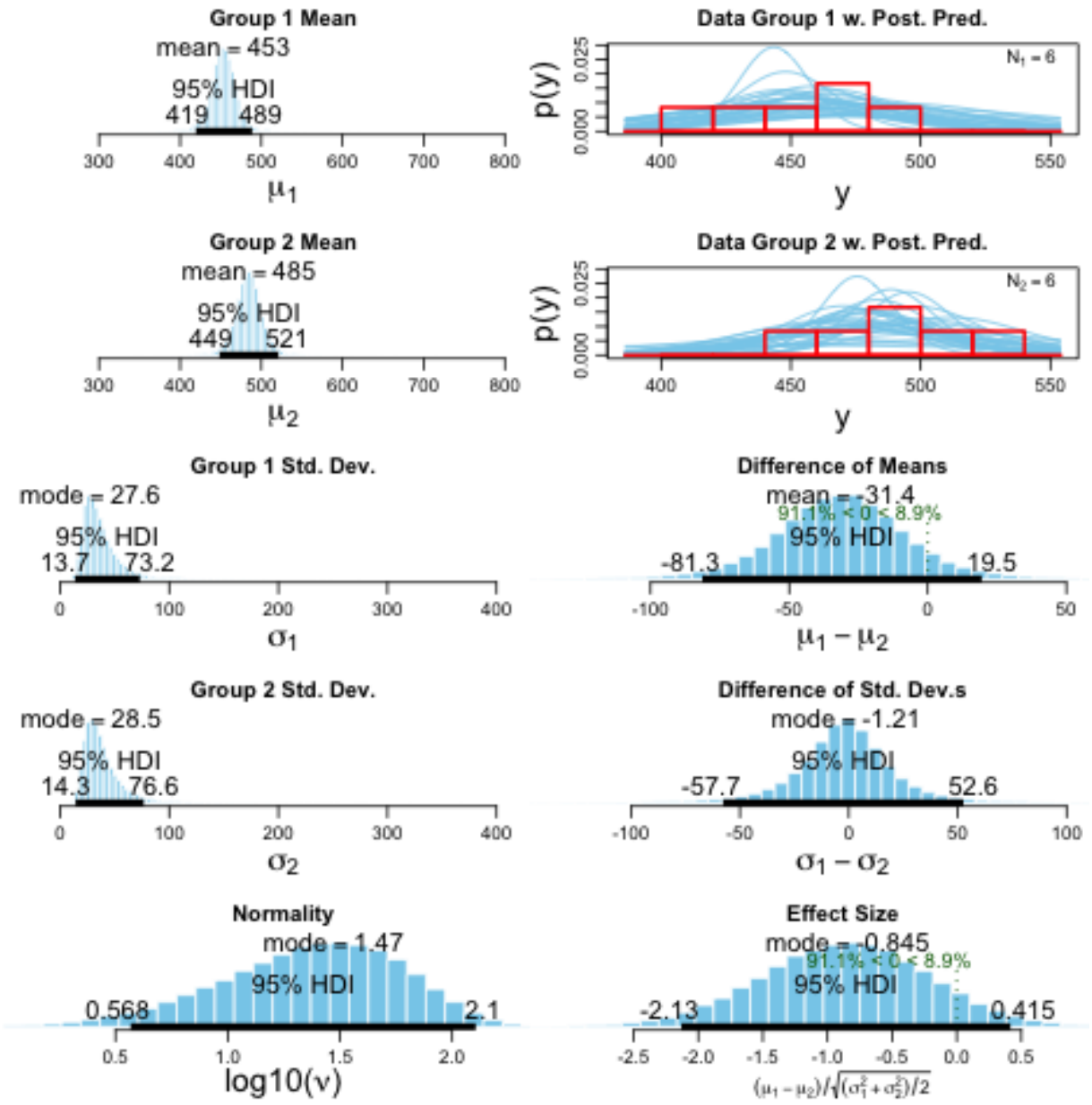


Figure 12: Eriksen-Flanker (incongruent)

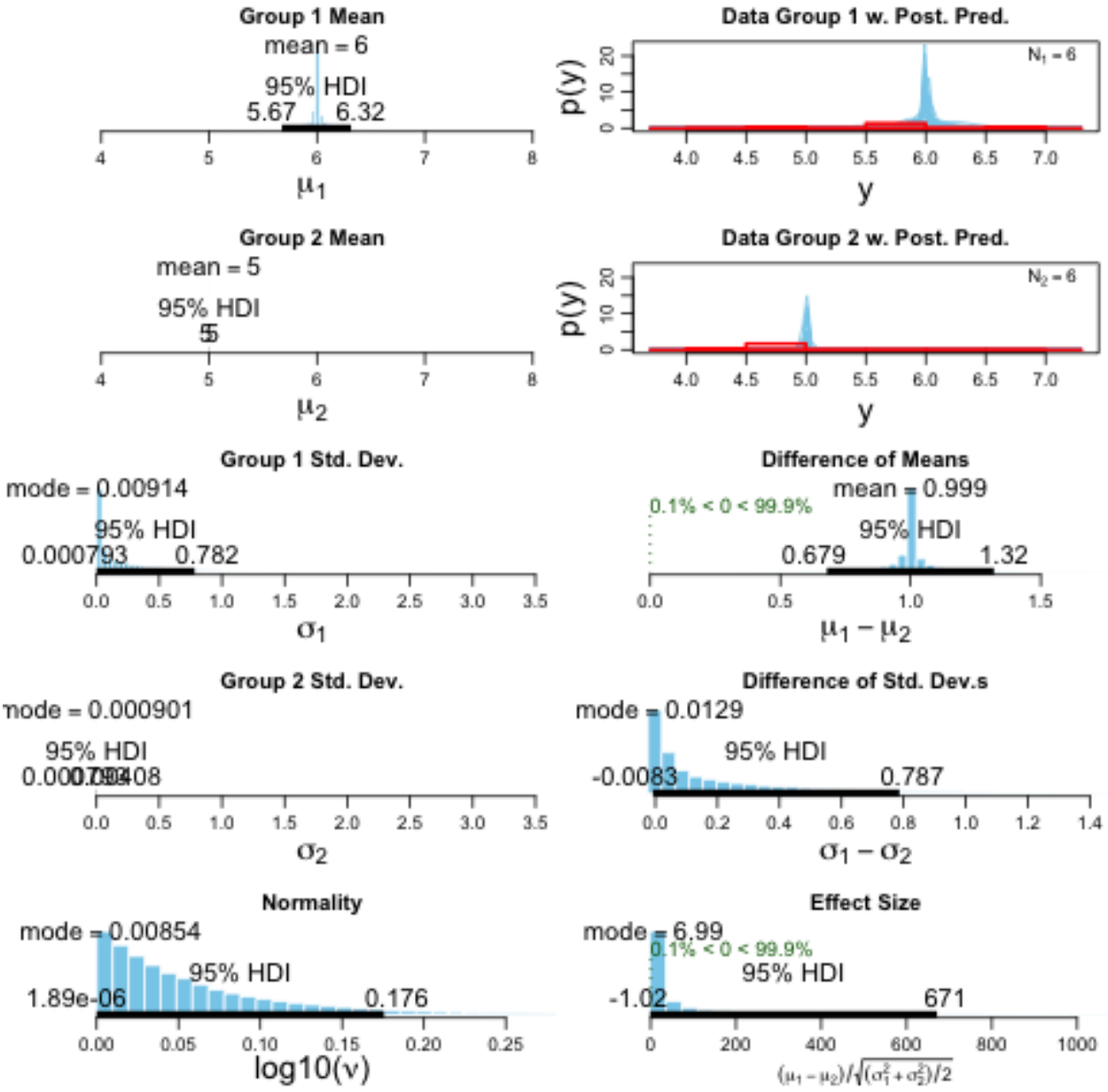


Figure 13: Corsi Forward

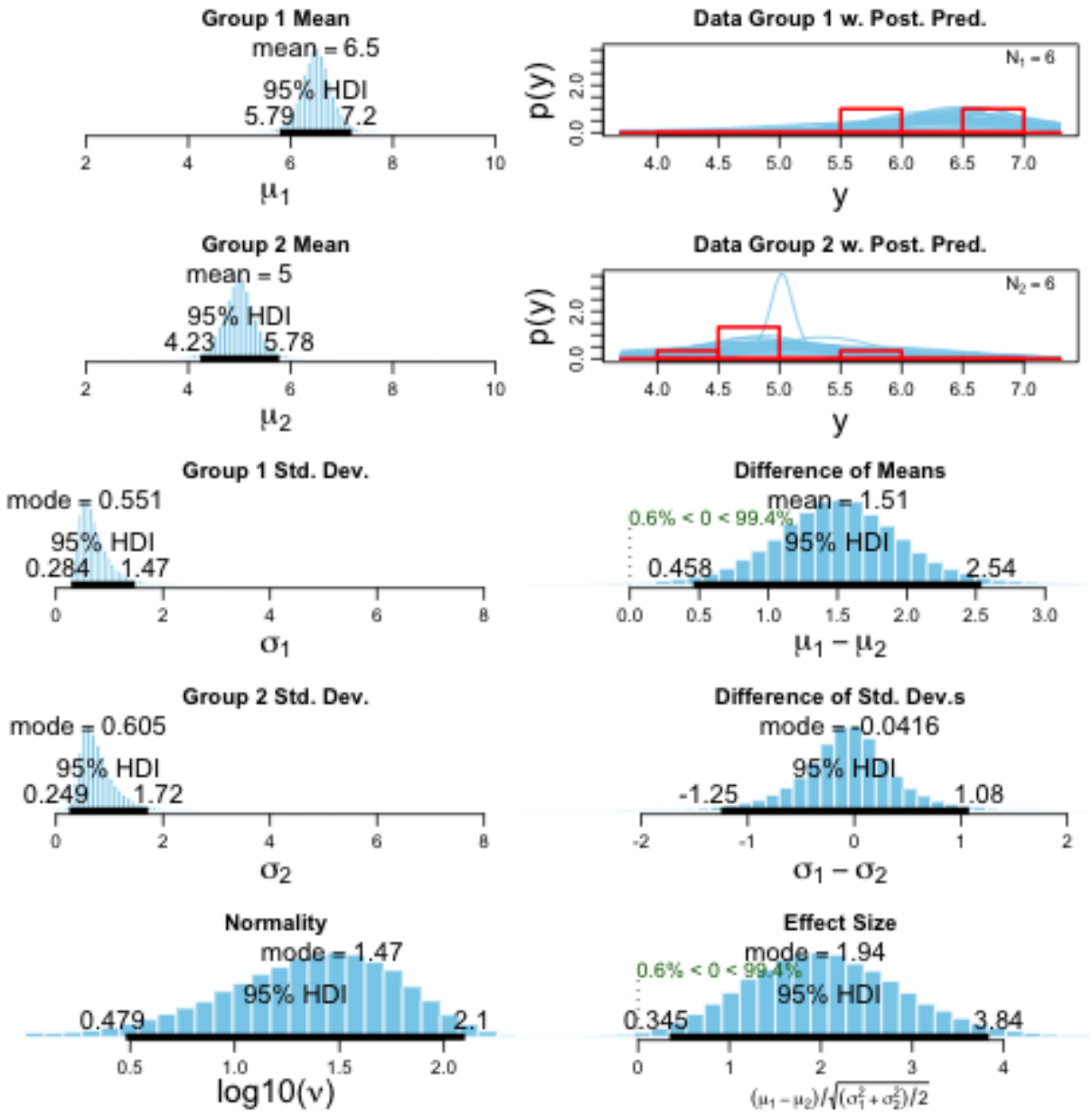


Figure 14: Corsi Backward

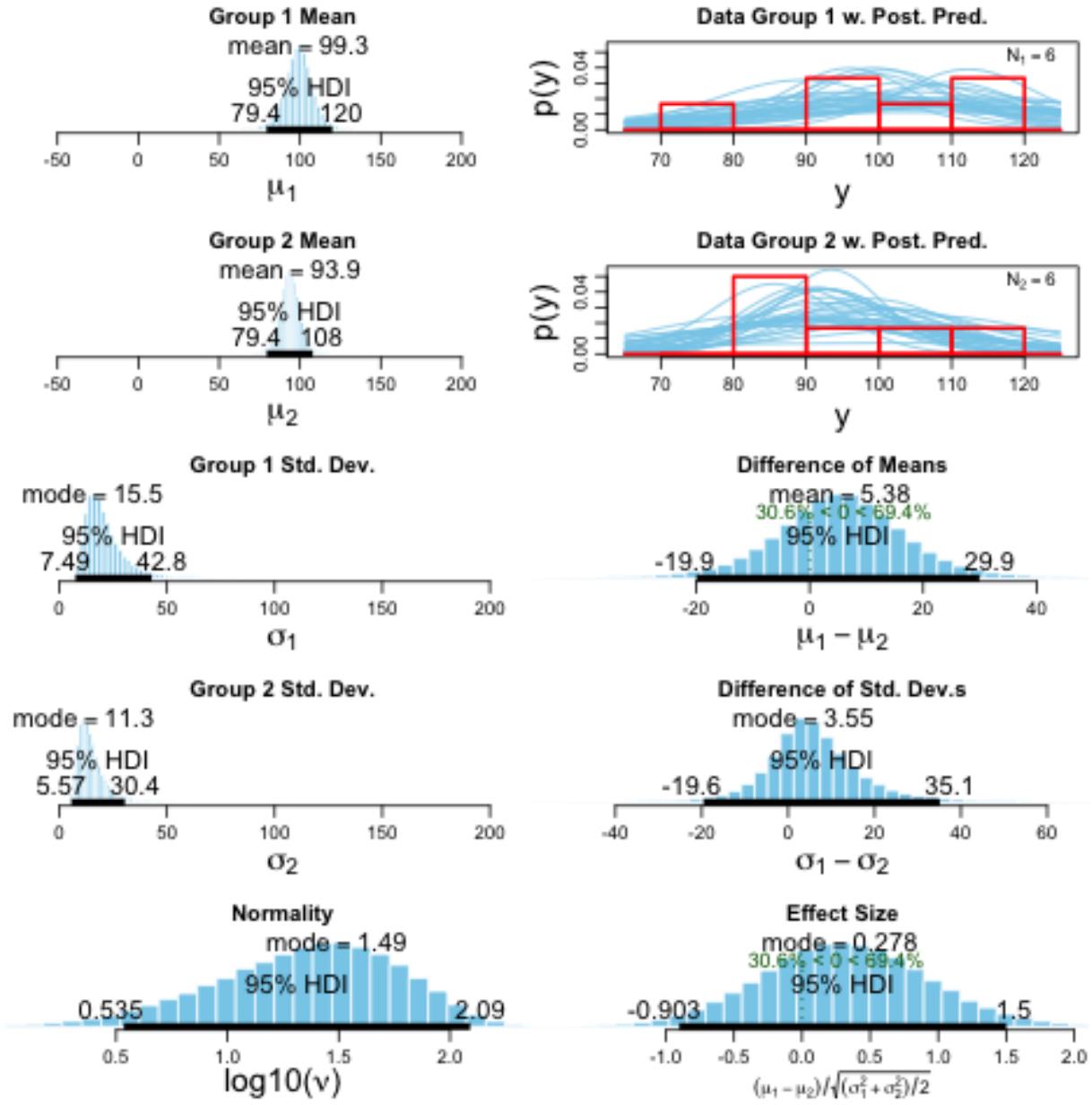


Figure 15: SART (Go)

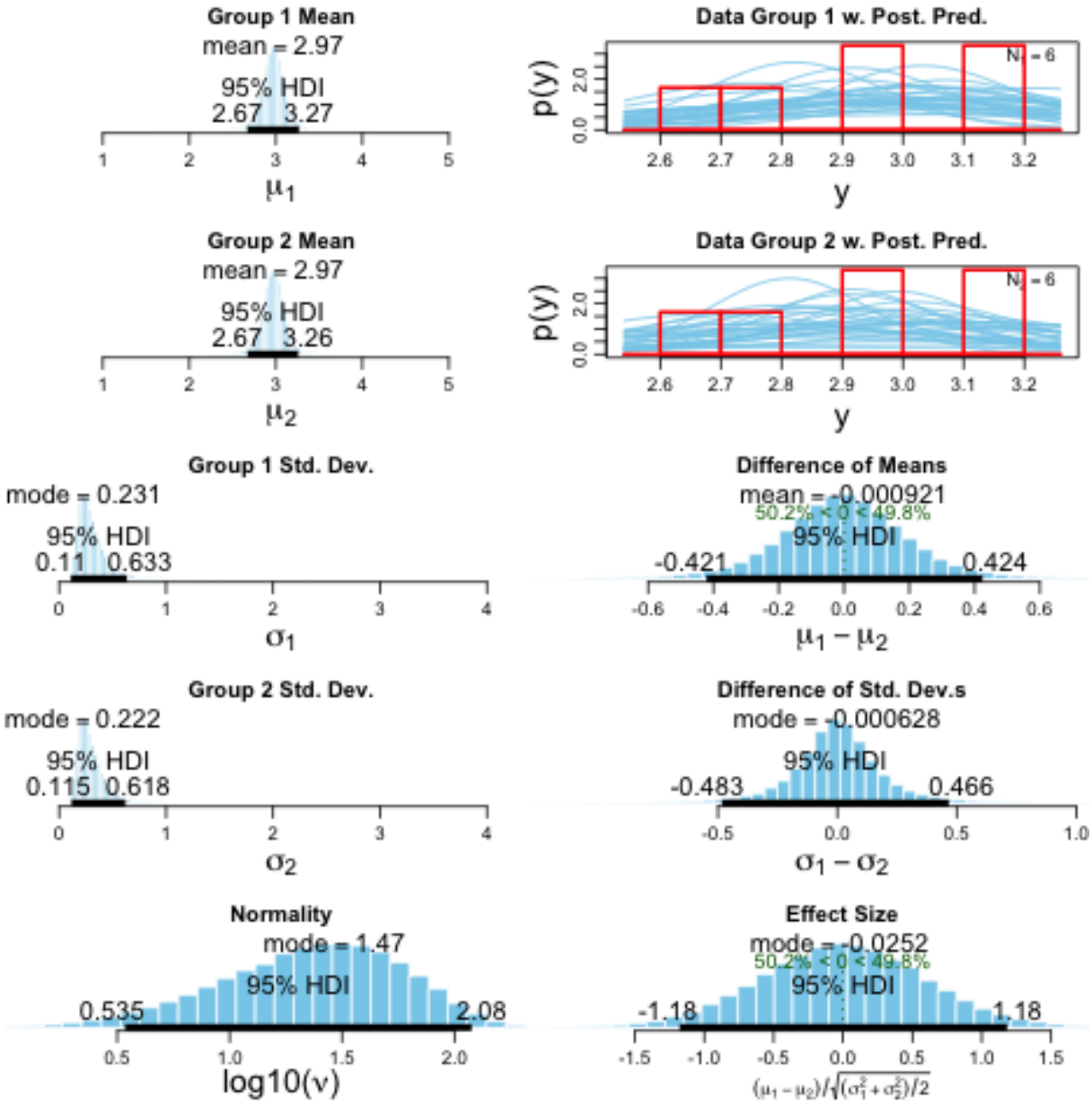


Figure 16: Dual 'n' Back (average)

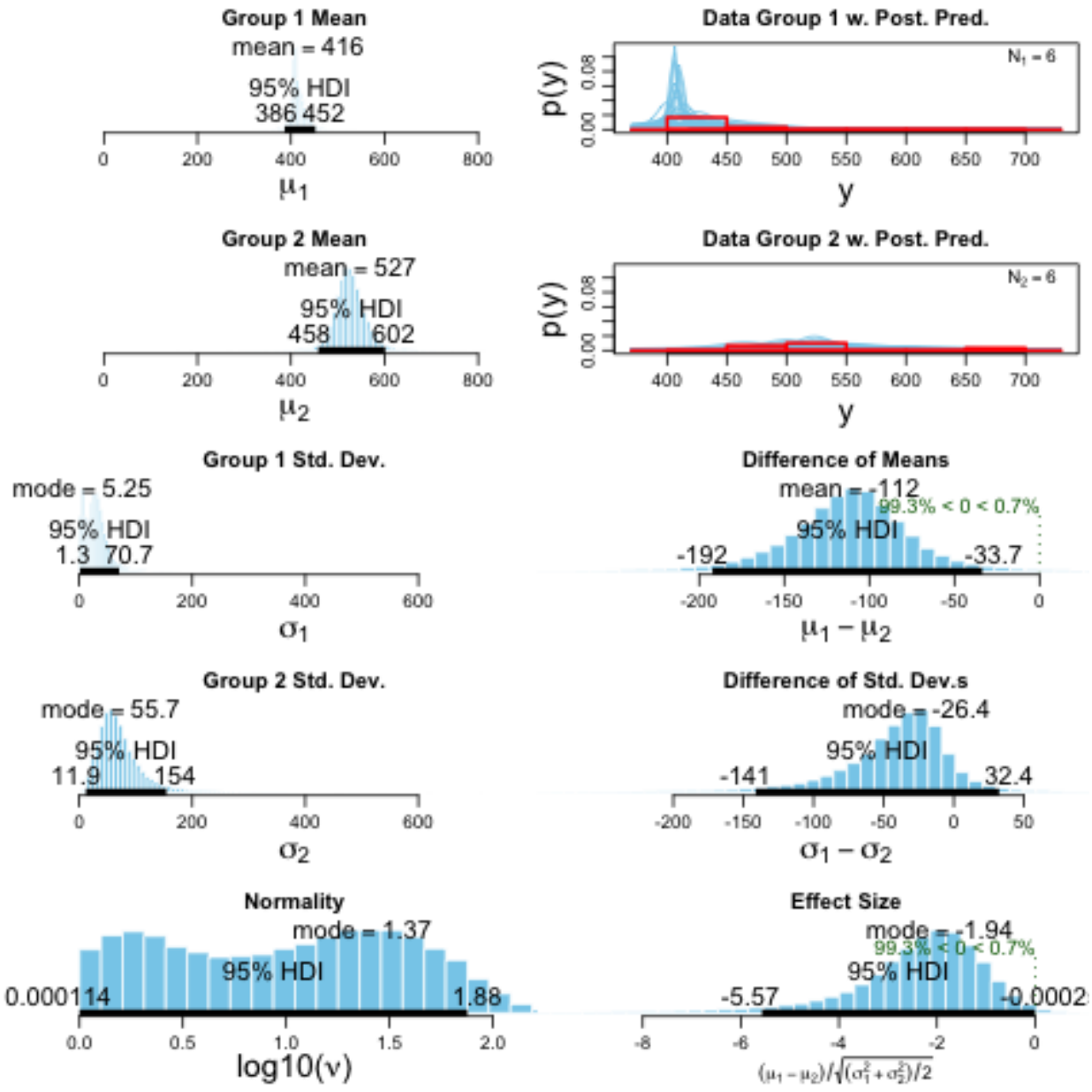


Figure 17: PRP (SOA=75)

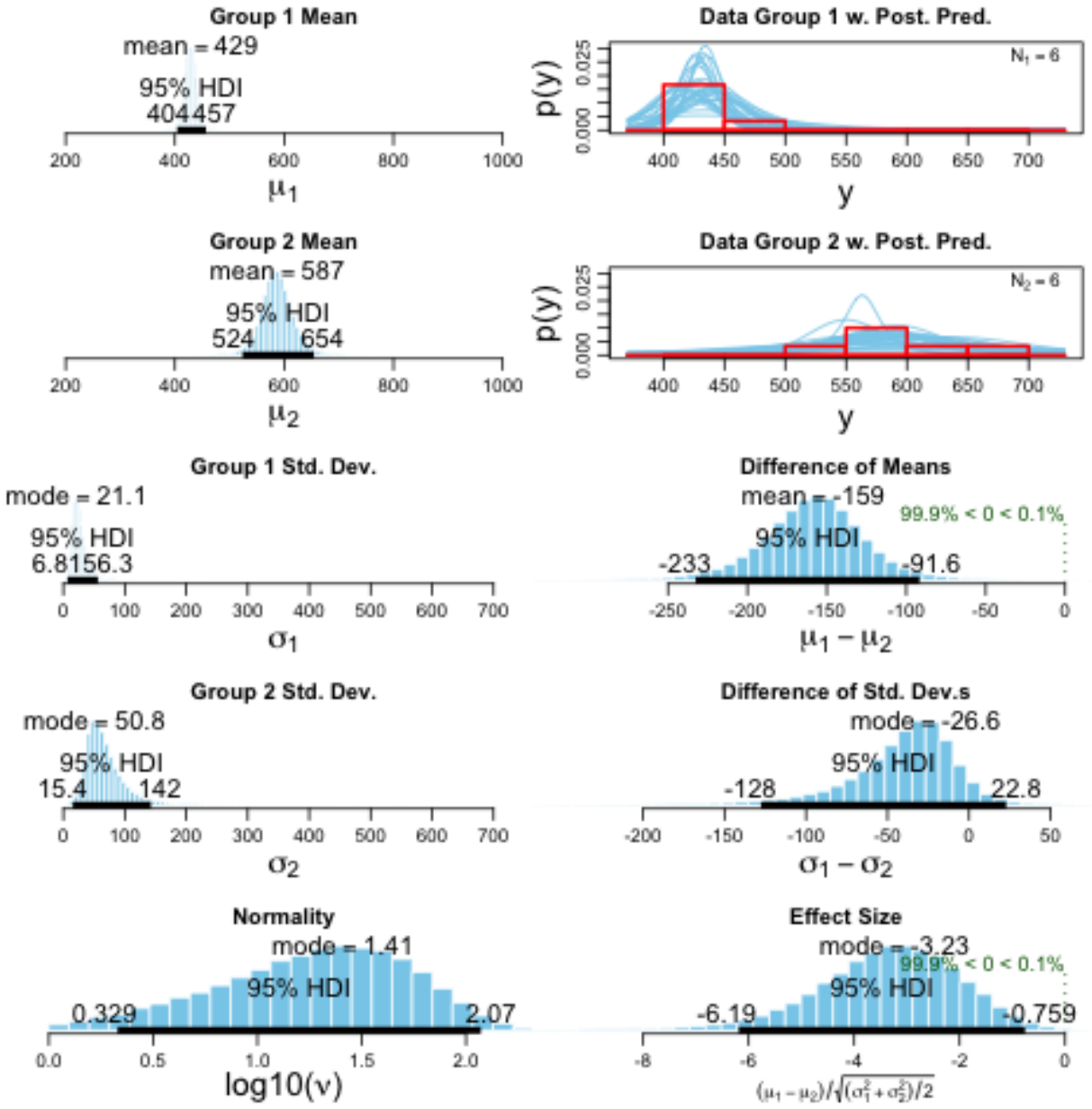


Figure 18: PRP (SOA=150)

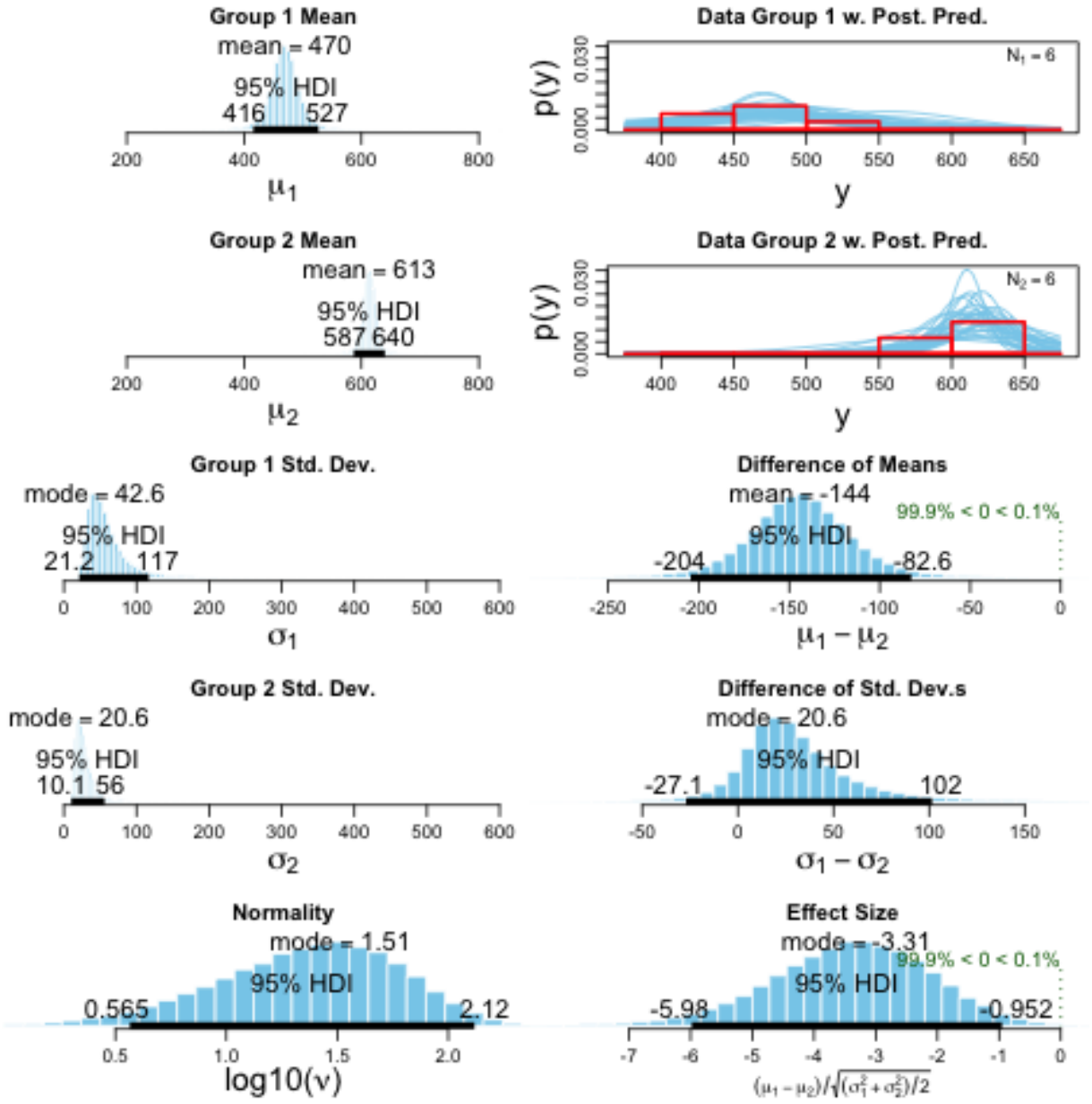


Figure 19: PRP (SOA=300)

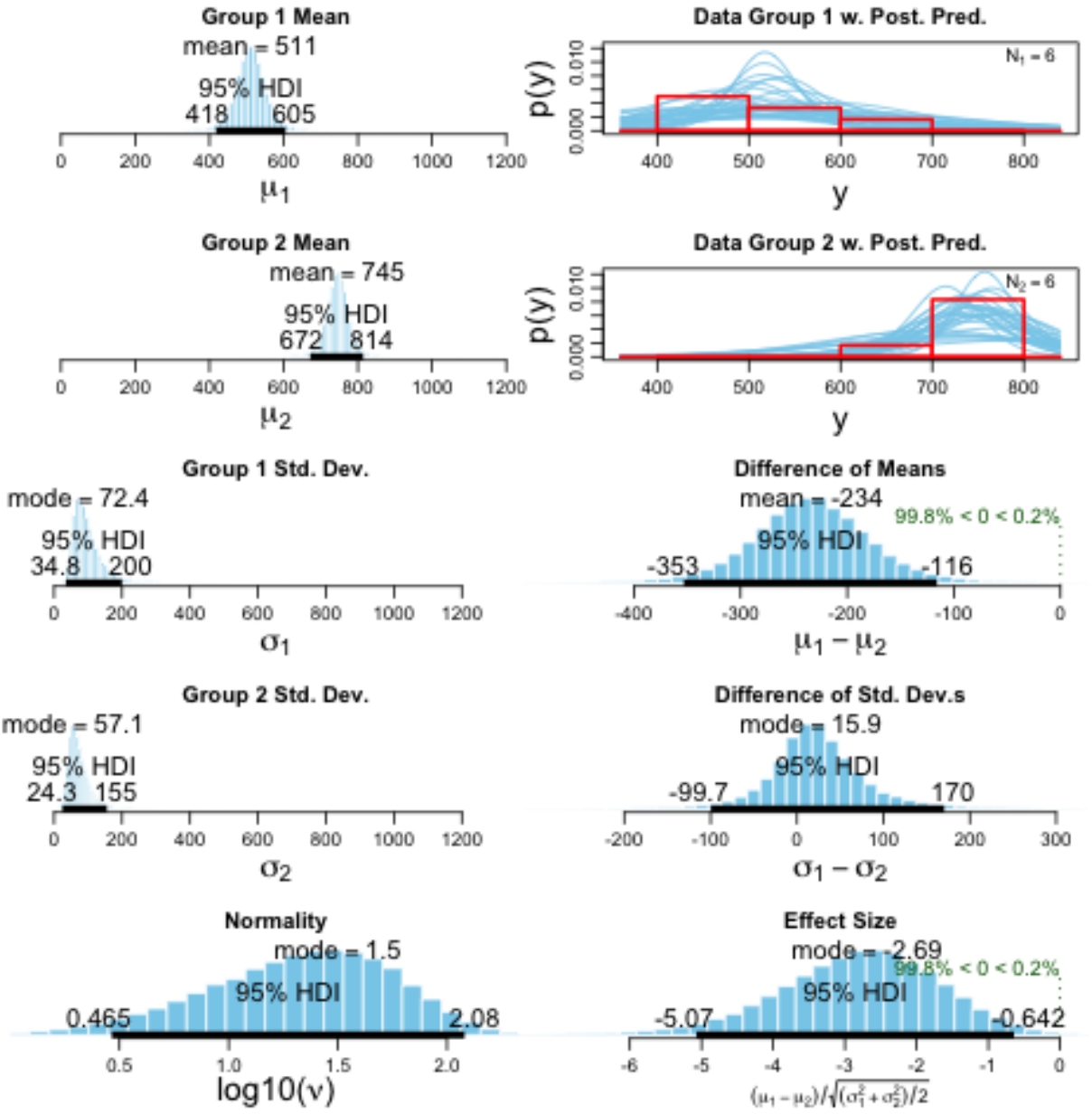


Figure 20: PRP (SOA=600)

```
> t.test(period_Bfinal %>% pull(`Deary-Liewald (single block)`), X2020 %>% pull(DL1), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Deary-Liewald (single block)`) and X2020 %>% pull(DL1)
t = -2.2091, df = 6.6688, p-value = 0.06477
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -29.237254   1.142016
sample estimates:
mean of x mean of y
 256.7321  270.7798

> t.test(period_Bfinal %>% pull(`Deary-Liewald (4 blocks)`), X2020 %>% pull(DL4), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Deary-Liewald (4 blocks)`) and X2020 %>% pull(DL4)
t = -4.9176, df = 6.0617, p-value = 0.002588
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -51.68669 -17.39664
sample estimates:
mean of x mean of y
 319.2292  353.7708

>
> t.test(period_Bfinal %>% pull(`Task Switching (switch - 1)`), X2020 %>% pull(TS1), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Task Switching (switch - 1)`) and X2020 %>% pull(TS1)
t = -5.8071, df = 9.8449, p-value = 0.000182
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -153.79660  -68.37007
sample estimates:
mean of x mean of y
 453.8864  564.9697
```

```
> t.test(period_Bfinal %>% pull(`Task Switching (repeat -0)`), X2020 %>% pull(TS0), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Task Switching (repeat -0)`) and X2020 %>% pull(TS0)
t = -6.6356, df = 9.9357, p-value = 5.994e-05
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -109.30636  -54.31609
sample estimates:
mean of x mean of y
 423.2381  505.0493

>
> t.test(period_Bfinal %>% pull(`Posner Cueing (Cued – 1)`), X2020 %>% pull(PC1), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Posner Cueing (Cued – 1)`) and X2020 %>% pull(PC1)
t = -8.4058, df = 9.694, p-value = 9.3e-06
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -106.10596  -61.49025
sample estimates:
mean of x mean of y
 263.5217  347.3198

> t.test(period_Bfinal %>% pull(`Posner Cueing (Uncued - 0)`), X2020 %>% pull(PC1), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Posner Cueing (Uncued - 0)`) and X2020 %>% pull(PC1)
t = -5.0242, df = 9.9773, p-value = 0.0005221
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -80.40915 -30.99060
sample estimates:
mean of x mean of y
 291.6199  347.3198
```

```
> t.test(period_Bfinal %>% pull(`Stroop (Compatible - 1)`), X2020 %>% pull(S1), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Stroop (Compatible - 1)`) and X2020 %>% pull(S1)
t = -2.0077, df = 9.8707, p-value = 0.07282
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -73.184553   3.872985
sample estimates:
mean of x mean of y
 461.4306  496.0863

> t.test(period_Bfinal %>% pull(`Stroop (Incompatible - 0)`), X2020 %>% pull(S0), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Stroop (Incompatible - 0)`) and X2020 %>% pull(S0)
t = -3.8357, df = 7.8293, p-value = 0.005184
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -120.44079  -29.78304
sample estimates:
mean of x mean of y
 527.7062  602.8181

>
> t.test(period_Bfinal %>% pull(`Eriksen-Flanker (Congruent - 1)`), X2020 %>% pull(EF1), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Eriksen-Flanker (Congruent - 1)`) and X2020 %>% pull(EF1)
t = -3.1548, df = 9.8868, p-value = 0.01039
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -96.54566 -16.54709
sample estimates:
mean of x mean of y
 428.0817  484.6281
```

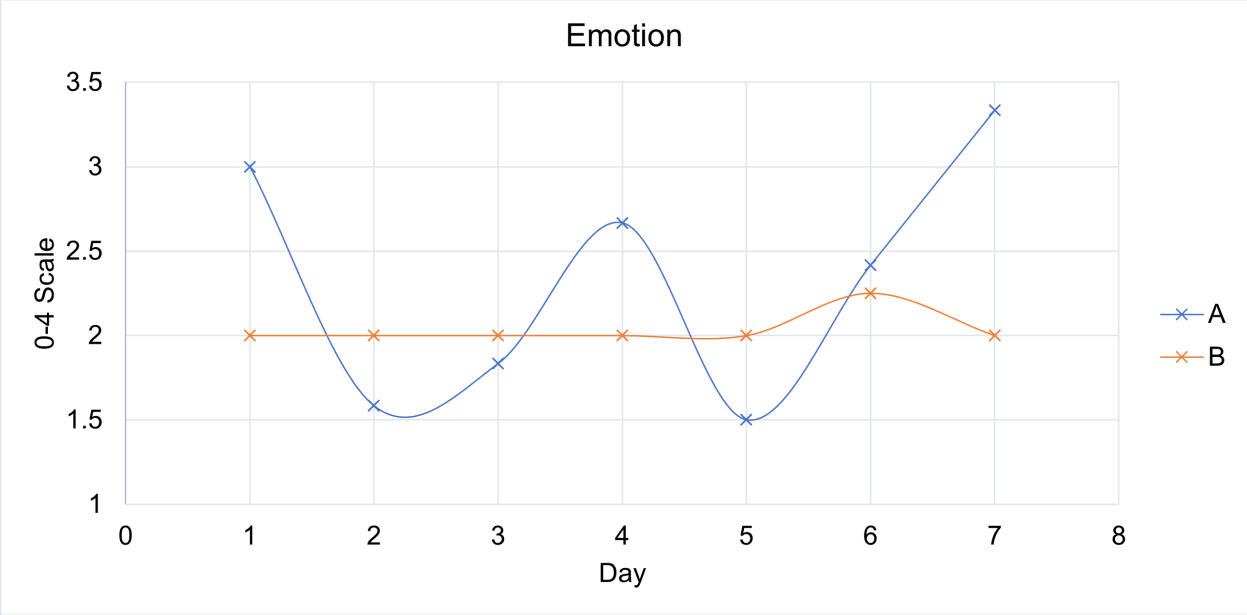
```
> t.test(period_Bfinal %>% pull(`Eriksen-Flanker (Incongruent - 0)`), X2020 %>% pull(EF0), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Eriksen-Flanker (Incongruent - 0)`) and X2020 %>% pull(EF0)
t = -1.9281, df = 9.9696, p-value = 0.08279
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -68.547653   4.962867
sample estimates:
mean of x mean of y
 452.8357  484.6281

>
> t.test(period_Bfinal %>% pull(`Corsi Forward`), X2020 %>% pull(CF), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Corsi Forward`) and X2020 %>% pull(CF)
t = 3.7963, df = 8.5503, p-value = 0.004658
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 0.4658509 1.8674824
sample estimates:
mean of x mean of y
 6.000000  4.833333

> t.test(period_Bfinal %>% pull(`Corsi Backward`), X2020 %>% pull(CB), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Corsi Backward`) and X2020 %>% pull(CB)
t = 4.3916, df = 9.8, p-value = 0.00142
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 0.7368351 2.2631649
sample estimates:
mean of x mean of y
      6.5       5.0
```

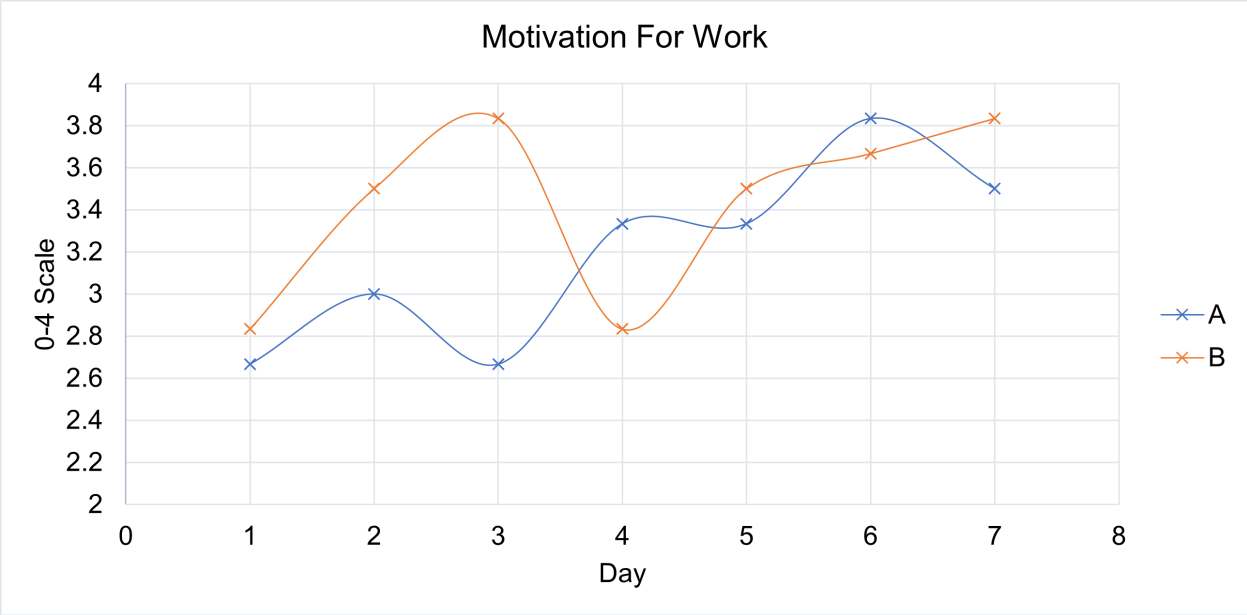
```
> t.test(period_Bfinal %>% pull(`SART (go) - 1`), X2020 %>% pull(SART1), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`SART (go) - 1`) and X2020 %>% pull(SART1)
t = 0.58988, df = 9.0551, p-value = 0.5697
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -13.64782  23.28825
sample estimates:
mean of x mean of y
 98.91358  94.09336

> t.test(period_Bfinal %>% pull(`SART (no go) - 0`), X2020 %>% pull(SART0), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`SART (no go) - 0`) and X2020 %>% pull(SART0)
t = 2.1034, df = 8.9556, p-value = 0.06491
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -12.50733 340.49749
sample estimates:
mean of x mean of y
 655.6803  491.6852

>
> t.test(period_Bfinal %>% pull(`Dual 'n' Back (average)`), X2020 %>% pull(DNBA), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`Dual 'n' Back (average)`) and X2020 %>% pull(DNBA)
t = 0, df = 10, p-value = 1
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.3007758  0.3007758
sample estimates:
mean of x mean of y
 2.966667  2.966667
```

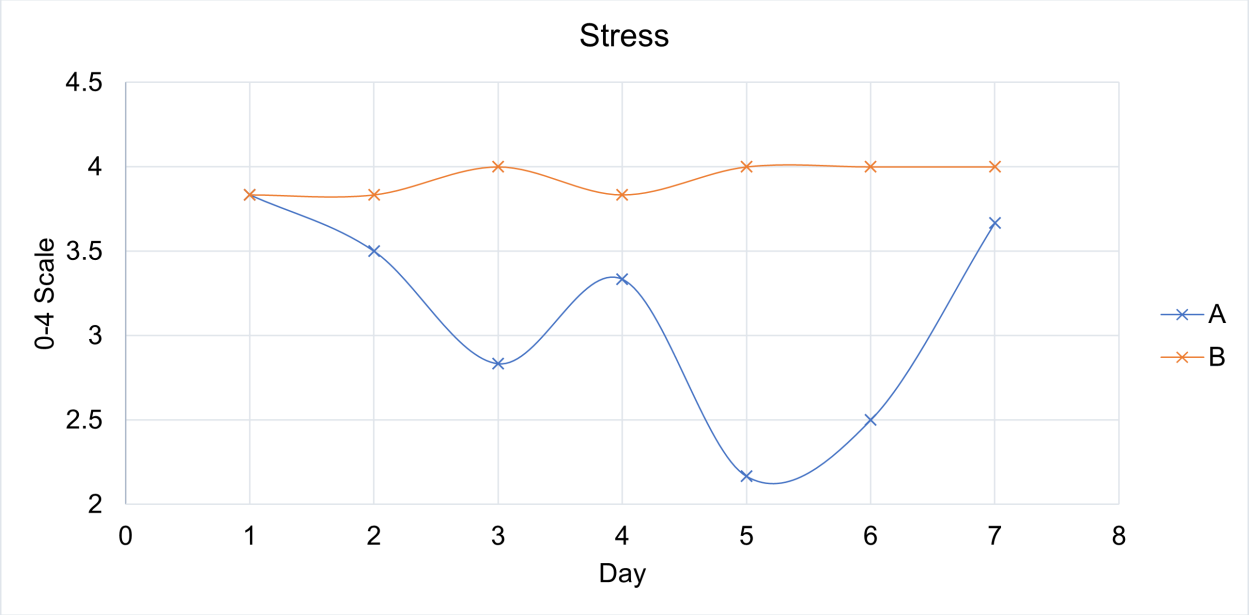
```
> t.test(period_Bfinal %>% pull(`PRP (soa - diff = 75)`), X2020 %>% pull(PRP75), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`PRP (soa - diff = 75)`) and X2020 %>% pull(PRP75)
t = -3.9607, df = 7.3078, p-value = 0.005004
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -180.97384  -46.38507
sample estimates:
mean of x mean of y
 420.5785  534.2579

> t.test(period_Bfinal %>% pull(`PRP (soa = 150)...20`), X2020 %>% pull(PRP150), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`PRP (soa = 150)...20`) and X2020 %>% pull(PRP150)
t = -6.6381, df = 6.5117, p-value = 0.0004005
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -219.0581 -102.6818
sample estimates:
mean of x mean of y
 430.3257  591.1956

> t.test(period_Bfinal %>% pull(`PRP (soa = 300)...21`), X2020 %>% pull(PRP300), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`PRP (soa = 300)...21`) and X2020 %>% pull(PRP300)
t = -7.1938, df = 7.2296, p-value = 0.0001528
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -189.47517  -96.18017
sample estimates:
mean of x mean of y
 470.2710  613.0986
```

```
> t.test(period_Bfinal %>% pull(`PRP (soa - diff = 600)`), X2020 %>% pull(PRP600), parallel=FALSE)

        Welch Two Sample t-test

data:  period_Bfinal %>% pull(`PRP (soa - diff = 600)`) and X2020 %>% pull(PRP600)
t = -5.8651, df = 9.401, p-value = 0.0002018
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -318.0542 -141.8265
sample estimates:
mean of x mean of y
 512.7437  742.6840
```

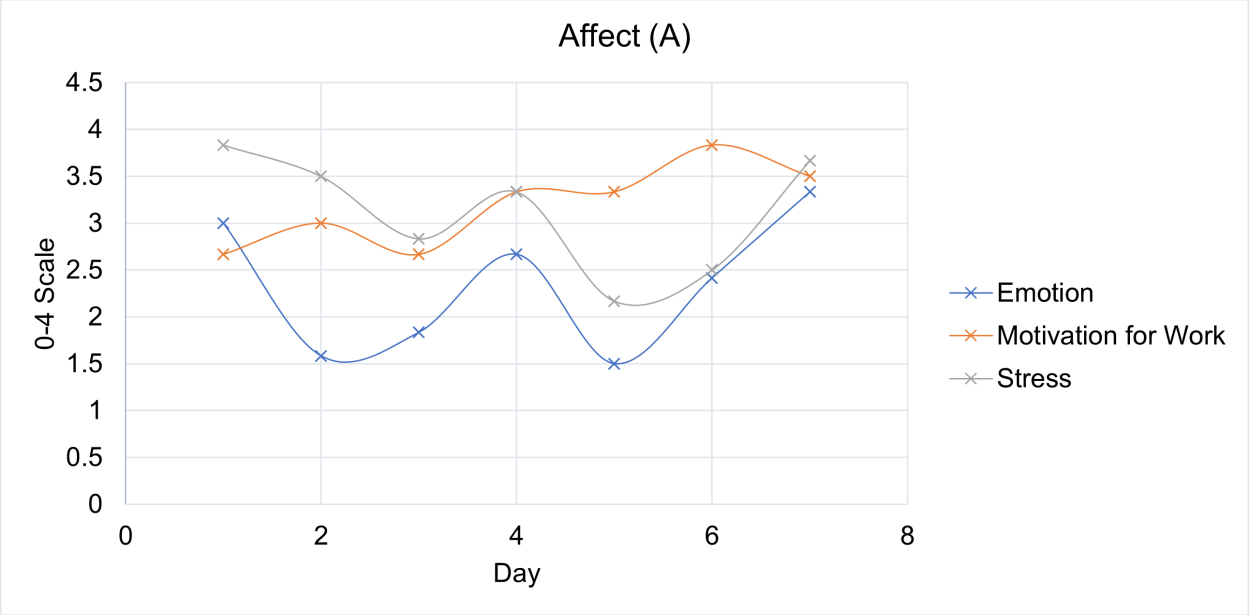
4.2 Affect


Emotion
3.5
3
2.5
2
1.5
1
0-4 Scale
0
1
2
3
4
5
6
7
8
Day
A
B

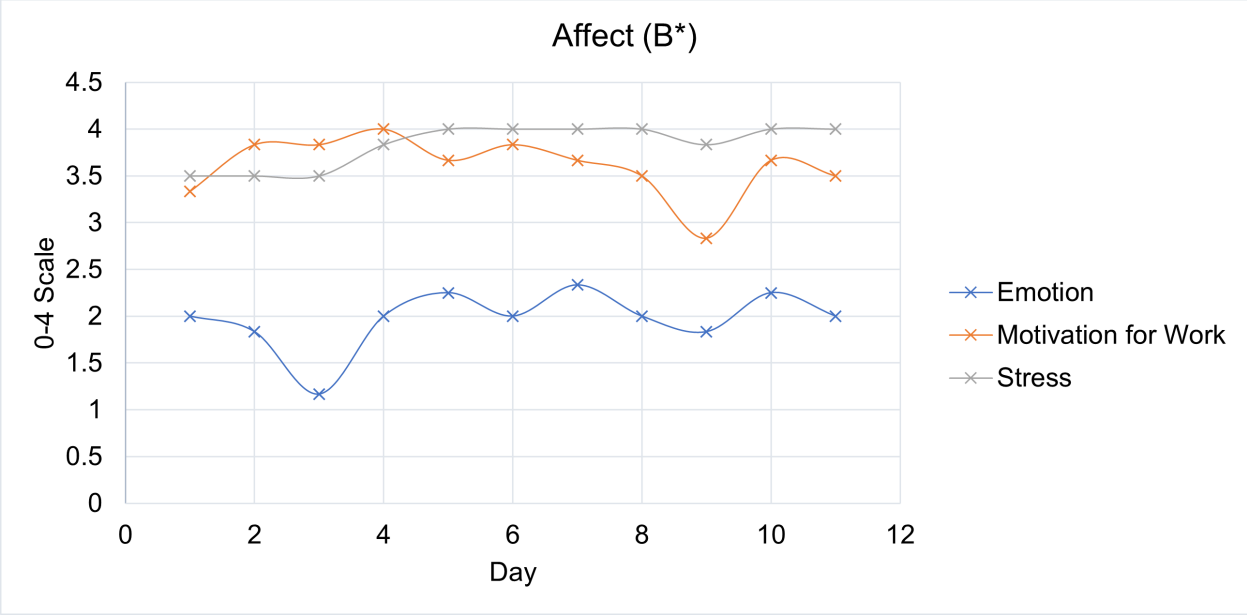

Motivation For Work
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
0-4 Scale
0
1
2
3
4
5
6
7
8
Day
A
B


Stress
4.5
4
3.5
3
2.5
2
0-4 Scale
0
1
2
3
4
5
6
7
8
Day
A
B

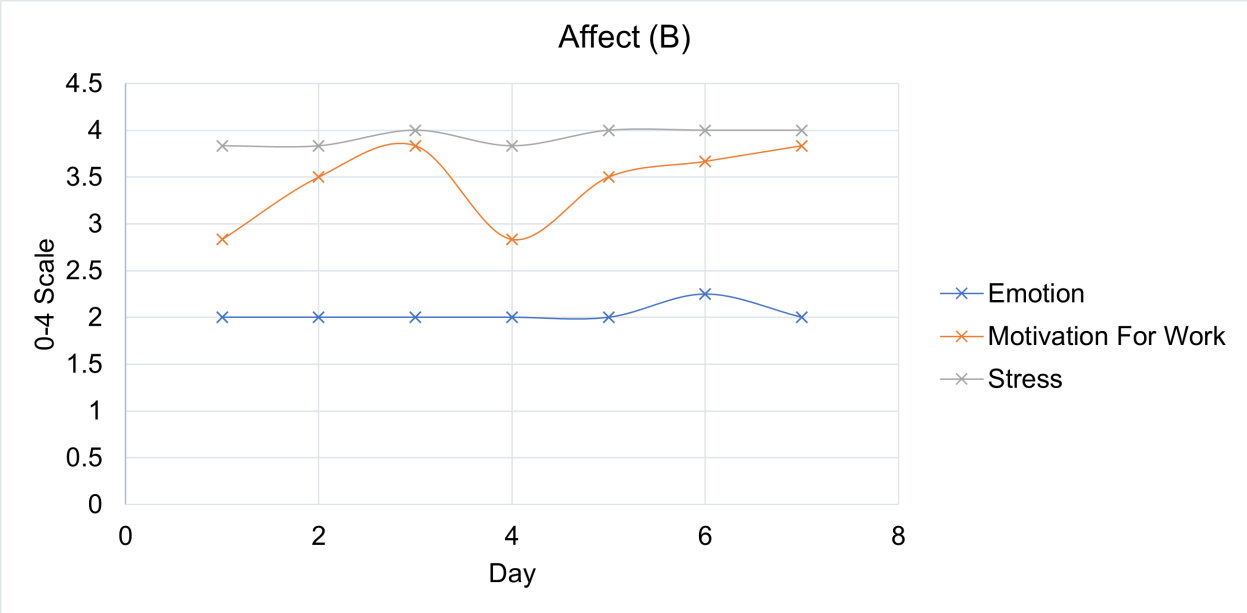
4.2.1 Period A


Affect (A)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
0-4 Scale
0
2
4
6
8
Day
Emotion
Motivation for Work
Stress

4.2.2 Period B*



4.2.3 Period B



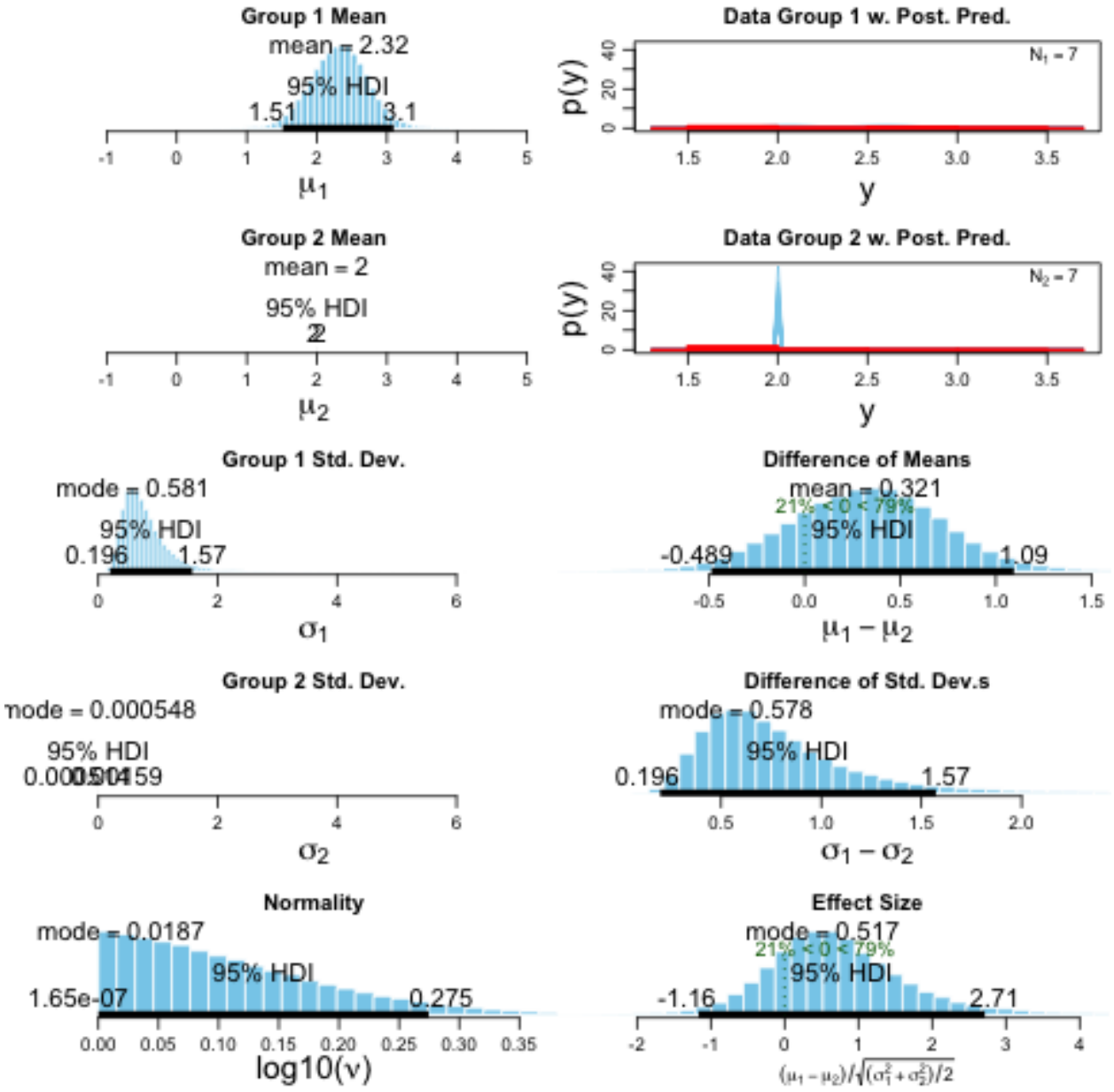


Figure 21: Emotion

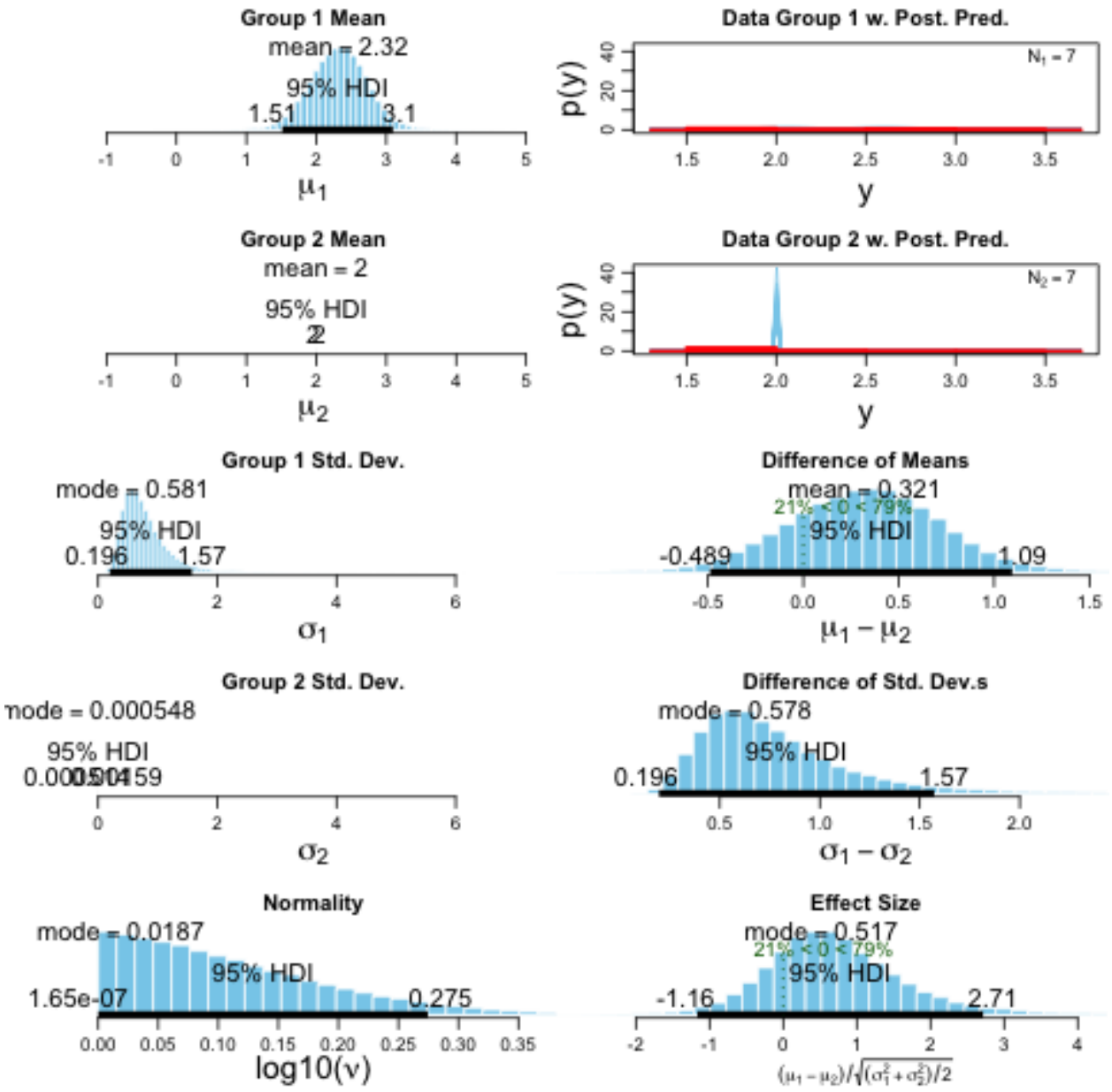


Figure 22: Motivation For Work

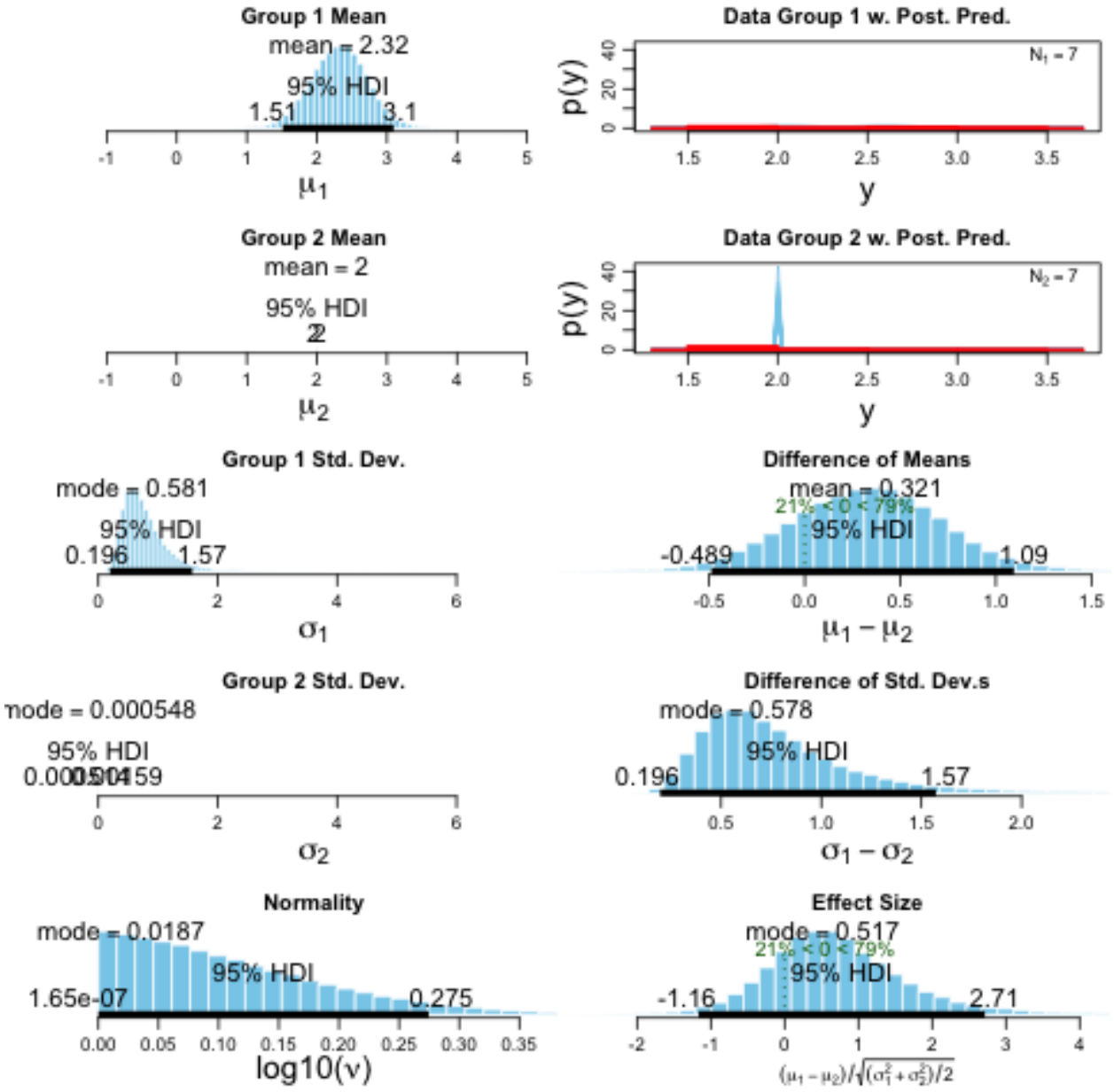


Figure 23: Stress

```
> t.test(Affect %>% pull(EA), Affect %>% pull(EB), parallel=FALSE)

        Welch Two Sample t-test

data:  Affect %>% pull(EA) and Affect %>% pull(EB)
t = 1.0914, df = 6.2094, p-value = 0.3156
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.3642030  0.9594411
sample estimates:
mean of x mean of y
 2.333333  2.035714

> t.test(Affect %>% pull(MFWA), Affect %>% pull(MFWB), parallel=FALSE)

        Welch Two Sample t-test

data:  Affect %>% pull(MFWA) and Affect %>% pull(MFWB)
t = -1.0314, df = 11.998, p-value = 0.3227
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.7410678  0.2648773
sample estimates:
mean of x mean of y
 3.190476  3.428571

> t.test(Affect %>% pull(SA), Affect %>% pull(SB), parallel=FALSE)

        Welch Two Sample t-test

data:  Affect %>% pull(SA) and Affect %>% pull(SB)
t = -3.372, df = 6.2407, p-value = 0.01413
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -1.3915080 -0.2275396
sample estimates:
mean of x mean of y
 3.119048  3.928571
```

Figure 24: T-test of Emotion, Motivation for Work and Stress respectively

A variance test was also done, to determine whether fluctuations in mood, stress or motivation changed due to supplementation.

```
> var.test(Affect %>% pull(EA), Affect %>% pull(EB), parallel=FALSE)

        F test to compare two variances

data:  Affect %>% pull(EA) and Affect %>% pull(EB)
F = 57.296, num df = 6, denom df = 6, p-value = 9.837e-05
alternative hypothesis: true ratio of variances is not equal to 1
95 percent confidence interval:
   9.845136 333.450497
sample estimates:
ratio of variances
           57.2963

> var.test(Affect %>% pull(MFWA), Affect %>% pull(MFWB), parallel=FALSE)

        F test to compare two variances

data:  Affect %>% pull(MFWA) and Affect %>% pull(MFWB)
F = 1.0288, num df = 6, denom df = 6, p-value = 0.9734
alternative hypothesis: true ratio of variances is not equal to 1
95 percent confidence interval:
 0.1767732 5.9872316
sample estimates:
ratio of variances
          1.028777

> var.test(Affect %>% pull(SA), Affect %>% pull(SB), parallel=FALSE)

        F test to compare two variances

data:  Affect %>% pull(SA) and Affect %>% pull(SB)
F = 49.833, num df = 6, denom df = 6, p-value = 0.0001478
alternative hypothesis: true ratio of variances is not equal to 1
95 percent confidence interval:
   8.562787 290.017870
sample estimates:
ratio of variances
          49.83333
```

Figure 25: F-test of Emotion, Motivation for Work and Stress respectively

5 Discussion and Conclusion

Period B* -
The cognitive tests that saw a statistically significant (through use of linear regression) improvement were: Deary-Liewald (single and four blocks), Task Switching (switch, and repeat), Stroop (Incompatible), Psychological Refractory Period (all SOAs) and SART (no-go) once weighted against its error.

The cognitive tests that saw a statistically significant (through use of a sign test) improvement were all tasks apart from Stroop (compatible), (which was eliminated previously from our statistical analysis as it had significant practice effects associated with it), SART (go), Corsi (forward and backward), and average Dual-n-Back score.

Period B -
Bayesian analysis (through use of the BEST package in R) and the Welsh t-test were used to compare the data from period A and B.

The cognitive tests that were found to have a statistically significant (through the use of a Welsh t-test) improvement from period A to B, were:

Test:	**p-Value:**	**Effect Size:**	**Difference In Mean Between A and B :**
Deary-Liewald (four blocks)	0.003	-2.31	-33.9
Task Switching (switch)	0.0002	-2.64	-113
Task Switching (repeat)	0.00006	-2.99	-82
Posner Cueing (cued)	0.000009	-3.63	-84.4
Posner Cueing (uncued)	0.0005	-2.27	-56.8
Stroop (incompatible)	0.005	-1.71	-74
Eriksen-Flanker (incongruent)	0.01	-0.845	-31.4
Corsi Forward	0.005	6.99	1
Corsi Backward	0.001	1.94	1.5
PRP (SOA = 75)	0.005	-1.94	-26.4
PRP (SOA = 150)	0.0004	-3.23	-26.6
PRP (SOA = 300)	0.0001	-3.31	-82.6
PRP (SOA = 600)	0.0002	-2.69	-234

The Affect variables that were found to have a statistically significant (through the use of a Welsh t-test) improvement from period A to B, were:

Variable:	**p-Value:**	**Effect Size:**	**Difference in Means Between A and B:**
Stress	0.01	0.517	0.321

Although, emotion or motivation for work did not have statistically significant changes, fluctuation (variance) for emotion/mood did decrease significantly (p=0.0001) over the experiment.

Effect size is defined as "the amount of change induced by the treatment relative to the standard deviation, or in other words the "standardized" change." [30]

An effect size ≥ 3 implies that more than 99 percent of people who would supplement with Ashwagandha would see an improvement in their score.
An effect size ≥ 2 implies that more than 98 percent of people who would supplement with Ashwagandha would see an improvement in their score.
An effect size of 1.7 (Stroop) implies that more than 95 percent of people who would supplement with Ashwagandha would see an improvement in their score.
An effect size of 0.5 (Stress) implies that 69 percent of people who would supplement with Ashwagandha would see an improvement in their score.
[11]

Although our results are positive, they are unnaturally high - and it would be prudent to view them with a grain (or bag) of salt.

What can be concluded from this research is that supplementation of Ashwagandha can improve scores in certain cognitive tests; and if one believes that test such as these can be an accurate predictor of real life brain function, then from these results Ashwagandha can be seen to improve:

- Choice reaction time
- Ability to unconsciously shift attention from one task to another
- (Possibly) processing speed
- (Possibly) attention capacity
- (Possibly) Short term working memory
- Dual-tasking (ability to complete two tasks in rapid succession)

Supplementation of Ashwagandha has also been found to improve stress levels by 8%, and decrease variation in mood.

Ashwagandha does not seem to be able to improve:

- Simple reaction time
- (Possibly) processing speed
- (Possibly) attention capacity
- (Possibly) Short term working memory
- Impulse/inhibitory control

Comparing our results to the literature specifically that of Pingali et al), in which it was found (in healthy male subjects) that over a 14 day period simple reaction time can be decreased by 6%. In our study a reduction of 10% was seen for the reaction time test Deary-Liewald (4 blocks), which is comparable.

The other tests performed by Pingali and et could not justifiably be compared to the tests performed in this research.

From the study: "Significant improvements were observed in reaction times with simple reaction, choice discrimination, digit symbol substitution, digit vigilance, and card sorting tests with Withania somnifera extract compared to placebo. However, no effect can be seen with the finger tapping test."

It has been found here that Ashwagandha could improve attention shifts, processing speed, attention capacity, dual tasking and working memory - conclusions which have not been found previously in the literature. Therefore, the extent to which self-experiments could benefit our collective knowledge of nootropics is huge.

In retrospect, the use of so many tests (although useful) did create a mental burden, especially as this experiment was run alongside my university degree, and as such, I would not recommend for other self-experimenters to design their experiment in this manner.

6 Further Work

Obviously, much work is required for self-experiments to be both accessible and informative for the community, however, as it is shown, studies such as this are feasible to undertake.

In designing and then employing my self-experiment the need for general guidelines was obvious - slight changes were made even during the experiment, and questions of how to analyse the data I was collecting were a constant irritation. Guidelines are also especially important if, in the future, studies such as this one are to be compared.

There are a few resources online, which I hope to condense into a working r/Nootropics self-studiers guide.

Further experiments should be done, for each individual cognitive processing category, with many more task, to confirm the above results. Self-experimenters should especially focus on working memory, processing speed and attention capacity, as analysis here was found to be inconclusive.

Bibliography

[1] Saul Mcleod. *Extraneous Variable*. Jan. 1970. URL: https://www.simplypsychology.org/extraneous-variable.html.

[2] David H. Barlow. "Single-Case Experimental Designs". In: *Archives of General Psychiatry* 29.3 (1973), p. 319. DOI: 10.1001/archpsyc.1973.04200030017003.

[3] Barbara A. Eriksen and Charles W. Eriksen. "Effects of noise letters upon the identification of a target letter in a nonsearch task". In: *Perception Psychophysics* 16.1 (1974), pp. 143–149. DOI: 10.3758/bf03203267.

[4] Arthur R. Jensen. "Reaction Time and Intelligence". In: *Intelligence and Learning* (1981), pp. 39–50. DOI: 10.1007/978-1-4684-1083-9_4.

[5] Colin M. Macleod. "Half a century of research on the Stroop effect: An integrative review." In: *Psychological Bulletin* 109.2 (1991), pp. 163–203. DOI: 10.1037/0033-2909.109.2.163.

[6] Harold Pashler. "Dual-task interference in simple tasks: Data and theory." In: *Psychological Bulletin* 116.2 (1994), pp. 220–244. DOI: 10.1037/0033-2909.116.2.220.

[7] Robert D. Rogers and Stephen Monsell. "Costs of a predictible switch between simple cognitive tasks." In: *Journal of Experimental Psychology: General* 124.2 (1995), pp. 207–231. DOI: 10.1037/0096-3445.124.2.207.

[8] Ian H Robertson et al. "'Oops!: Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects". In: *Neuropsychologia* 35.6 (1997), pp. 747–758. DOI: 10.1016/s0028-3932(97)00015-8.

[9] S Mcdonald et al. "Covert orienting and focusing of attention in children with attention deficit hyperactivity disorder". In: *Neuropsychologia* 37.3 (1999), pp. 345–356. DOI: 10.1016/s0028-3932(98)00078-5.

[10] Roy P. C. Kessels et al. "The Corsi Block-Tapping Task: Standardization and Normative Data". In: *Applied Neuropsychology* 7.4 (2000), pp. 252–258. DOI: 10.1207/s15324826an0704_8.

[11] Robert; Coe. *It's the effect size, stupid: what effect size is and why it is important*. Sept. 2002. URL: https://www.leeds.ac.uk/educol/documents/00002182.htm.

[12] IC; Cornoldi Mammarella. "Sequence and space: The critical role of a backward spatial span in the working memory deficit of visuospatial learning disabled children". In: *Cognitive Neuropsychology* 22.8 (2005), pp. 1055–1068. DOI: 10.1080/02643290442000509..

[13] G Natalucci et al. "Spontaneous 24-h ghrelin secretion pattern in fasting subjects: maintenance of a meal-related pattern". In: *European Journal of Endocrinology* 152.6 (2005), pp. 845–850. DOI: 10.1530/eje.1.01919.

[14] J. Dean. *Blurred Definitions of Affect and Emotion*. Nov. 2006. URL: https://www.spring.org.uk/2006/11/blurred-definitions-of-affect-and.php.

[15] Cecile A. Marczinski and Mark T. Fillmore. "Clubgoers and their trendy cocktails: Implications of mixing caffeine into alcohol on information processing and subjective reports of intoxication." In: *Experimental and Clinical Psychopharmacology* 14.4 (2006), pp. 450–458. DOI: 10.1037/1064-1297.14.4.450.

[16] Anne Germain and David J Kupfer. *Circadian rhythm disturbances in depression*. Oct. 2008. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2612129/#:~:text=In%20humans,%20mood%20also%20exhibits,changes%20in%20various%20circadian%20rhythms..

[17] Anna Wirz-Justice. *Diurnal variation of depressive symptoms*. 2008. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3181887/.

[18] McMorris T. Davrance K. Hall B. "Effect of acute exercise on cognitive control required during an eriksen flanker task". In: *Journal of Sport Exercise Psychology* 31.5 (2009), pp. 628–639. DOI: 0.1123/jsep.31.5.628.

[19] Sharon Chan and Miguel Debono. "Review: Replication of cortisol circadian rhythm: new advances in hydrocortisone replacement therapy". In: *Therapeutic Advances in Endocrinology and Metabolism* 1.3 (2010), pp. 129–138. DOI: 10.1177/2042018810380214.

[20] Susanne M. Jaeggi et al. "The concurrent validity of theN-back task as a working memory measure". In: *Memory* 18.4 (2010), pp. 394–412. DOI: 10.1080/09658211003702171.

[21] G Stoet. "A software package for programming psychological experiments using Linux". In: *Behavior Research Methods* 42.4 (2010), pp. 1096–1104.

[22] Malgorzata Lipowska, Ewa Czaplewska, and Anna Wysocka. "Visuospatial deficits of dyslexic children". In: *Medical Science Monitor* 17.4 (2011). DOI: 10.12659/msm.881718.

[23] Joris C. Verster and Thomas Roth. "Predicting psychopharmacological drug effects on actual driving performance (SDLP) from psychometric tests measuring driving-related skills". In: *Psychopharmacology* 220.2 (2011), pp. 293–301. DOI: 10.1007/s00213-011-2484-0.

[24] K. Chandrasekhar, Jyoti Kapoor, and Sridhar Anishetty. "A Prospective, Randomized Double-Blind, Placebo-Controlled Study of Safety and Efficacy of a High-Concentration Full-Spectrum Extract of Ashwagandha Root in Reducing Stress and Anxiety in Adults". In: *Indian Journal of Psychological Medicine* 34.3 (2012), pp. 255–262. DOI: 10.4103/0253-7176.106022.

[25] John K. Kruschke. "Bayesian Estimation Supersedes the t Test". In: *PsycEXTRA Dataset* (2012). DOI: 10.1037/e502412013-055.

[26] Michael I. Posner. "Orienting of Attention". In: *Attention in a Social World* (2012), pp. 49–71. DOI: 10.1093/acprof:oso/9780199791217.003.0003.

[27] Danielle I. Brady et al. "Conceptual and Perceptual Set-shifting executive abilities in young adults with Aspergers syndrome". In: *Research in Autism Spectrum Disorders* 7.12 (2013), pp. 1631–1637. DOI: 10.1016/j.rasd.2013.09.009.

[28] Adele Diamond. *Executive functions*. 2013. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4084861/.

[29] Usharani Pingali, Raveendranadh Pilli, and Nishat Fatima. "Effect of standardized aqueous extract of Withania somniferaon tests of cognitive and psychomotor performance in healthy human participants". In: *Pharmacognosy Research* 6.1 (2014), pp. 12–18. DOI: 10.4103/0974-8490.122912.

[30] John K. Kruschke. "The R Programming Language". In: *Doing Bayesian Data Analysis* (2015), pp. 33–70. DOI: 10.1016/b978-0-12-405888-0.00003-9.

[31] Dnyanraj Choudhary, Sauvik Bhattacharyya, and Sekhar Bose. "Efficacy and Safety of Ashwagandha (Withania somnifera (L.) Dunal) Root Extract in Improving Memory and Cognitive Functions". In: *Journal of Dietary Supplements* 14.6 (2017), pp. 599–612. DOI: 10.1080/19390211.2017.1284970.

[32] G Stoet. "A novel web-based method for running online questionnaires and reaction-time experiments." In: *Teaching of Psychology* 44.1 (2017), pp. 24–31.

[33] M. Vonmoos and B.b. Quednow. "Cognitive Dysfunctions in Chronic Cocaine Users". In: *The Neuroscience of Cocaine* (2017), pp. 395–405. DOI: 10.1016/b978-0-12-803750-8.00040-3.

[34] Deepak Langade et al. "Efficacy and Safety of Ashwagandha (Withania somnifera) Root Extract in Insomnia and Anxiety: A Double-blind, Randomized, Placebo-controlled Study". In: *Cureus* (2019). DOI: 10.7759/cureus.5797.

[35] Jim Frost et al. *How t-Tests Work: t-Values, t-Distributions, and Probabilities*. July 2020. URL: https://statisticsbyjim.com/hypothesis-testing/t-tests-t-values-t-distributions-probabilities/.

[36] Will Kenton. *T-Test Definition*. Sept. 2020. URL: https://www.investopedia.com/terms/t/t-test.asp.

[37] *APA Dictionary of Psychology*. URL: https://dictionary.apa.org/affect.

[38] "Circadian Rhythm (circadian clock)". In: *SpringerReference* (). DOI: 10.1007/springerreference_93486.

[39] Deary IJ;Liewald D;Nissan J; *A free, easy-to-use, computer-based simple and four-choice reaction time programme: the Deary-Liewald reaction time task*. URL: https://pubmed.ncbi.nlm.nih.gov/21287123/.

[40] Mara Mather Marisa Knight. *Look Out – It's Your Off-Peak Time of Day! Time of Day Matters More for Alerting than for Orienting or Executive Attention*. URL: https://gero.usc.edu/labs/matherlab/files/2019/03/KnightMather2013.pdf.

[41] *Psychological Refractory Period Paradigm Task*. URL: https://scienceofbehaviorchange.org/measures/psychological-refractory-period-paradigm-task/#:~:text=The%20Psychological%20Refractory%20Period%20(PRP)%20task%20measures%20the%20limit%20of,important%20for%20goal-directed%20behavior..