**Supplementary Materials**

**Part I – Results**

**Supplementary Fig. 1. Flow diagram of analysis plan.** Abbreviations: Actively Open-minded Thinking scale (AOT), Rational-Experiential Inventory (REI), National Adult Reading Test (NART), Barratt Impulsiveness Scale (BIS), Cognitive Reflection Test (CRT), incongruent base-rate (representativeness) vignettes (IBRV) Verbal-Cognitive Reflection Test (verbal-CRT), Sternberg task and n-back (2-back).

**Supplementary Table 1.** Demographic information.

|  |  |
| --- | --- |
|  | **Stimulation Groups** |
| **Demographics** | **Group 1** | **Group 2** | **Group 3** |
| **Sex (M/F)** | 6/10 | 7/9 | 8/8 |
| **Age (mean/SD)** | 25.70 (4.33) | 26.70 (3.21) | 25.88 (3.91) |
| **Religious**  | 10/6 | 5/11 | 6/10 |
| **Religiosity scale** | 2.56 | 0.93 | 1.31 |
| **Education** | 4.88 (1.60) | 5.56 (1.21) | 5.38 (1.25) |

*Note: Education represents the mean qualification level (minimum = 1 to maximum = 8* (*Gov.UK*, 2021)*.* Religious represents number of participants reporting “Yes”/ “No”. The religiosity scale is based on a scale from 1 (not at all religious) to 5 (very religious) (Pennycook et al., 2014). *Abbreviations: Standard Deviations (SD), females (F), and males (M). Group 1 (2 stimulation sessions), Group 2 (stimulation followed by sham) and Group 3 (sham only in a single session).*

**Supplementary Table 2.** Cognitive characteristics of all participants.

|  |  |
| --- | --- |
|  | Stimulation Groups |
| Cognitive Characteristics | **Group 1** | **Group 2** | **Group 3** |
| NART score | 121.06 (2.81) | 121.00 (2.28) | 119.31 (2.44) |
| AOT score | 37.81 (6.75) | 40.20 (5.13) | 42.70 (4.75) |
| REI 10 R sub-scale | 16.80 (4.84) | 15.90 (4.84) | 19.80 (3.61) |
| REI 10 E sub-scale | 14.81 (2.04) | 16.00 (2.16) | 15.56 (1.63) |

Note: The means are presented prior to standard deviations in parentheses. Abbreviations: National Adult Reading Test (NART), Actively Open-minded Thinking (AOT), Rational Experiential Inventory Rational sub-scale (REI 10 R), Rational Experiential Inventory Experiential sub-scale (REI 10 E). Group 1 (2 active stimulation sessions), Group 2 (active stimulation followed by sham) and Group 3 (sham only in a single session).

**Supplementary Table 3.** Means (and standard deviations) for theBarrett Impulsiveness Scale (BIS) second order results across experimental groups.

|  |  |
| --- | --- |
|  | **Stimulation Groups**  |
| **BIS 2nd order factors** | **Group 1** | **Group 2** | **Group 3** |
| Attentional | 17.90 (3.00) | 18.30 (4.30) | 18.80 (4.14) |
| Motor | 23.70 (3.07) | 24.20 (4.55) | 24.40 (3.74) |
| Non-planning | 25.80 (4.54) | 25.30 (6.02) | 24.30 (5.06) |

*Note*: BIS = Barrett Impulsiveness Scale. Group 1 (2 stimulation sessions), Group 2 (stimulation followed by sham) and Group 3 (sham only in a single session).

**Supplementary results for tests on cognitive characteristics variables**

To test for *a priori* differences between groups regarding cognitive characteristics, i.e., thinking styles and cognitive ability, a MANOVA was performed, with stimulation group (right DLPFC repeated active stimulation/Group 1, right DLPFC repeated active/sham stimulation group/Group 2, or single session sham/Group 3) as the between-subject factor. Dependent variables were the REI subscales: rational (REI 10 R) and experiential (REI 10 E), the Actively Open-minded Thinking scale (AOT) and the National Adult Reading Test (NART). The Box’s test results showed equality of covariance matrices *p* = 0.90. Using Wilks’ Lambda, there was a significant effect of stimulation group (Wilks’ Lambda = 0.67, F(8,84) = 2.27, *p* = 0.03) on cognitive characteristics. Follow-up ANOVAs are presented in Supplementary Table 6.

**Supplementary Table 4.** Follow-up ANOVAs for MANOVA differences in cognitive characteristics between stimulation groups.

|  |  |  |
| --- | --- | --- |
|  | **Follow-up ANOVAs** |  |
| **Dependent Variable** | **F** | **df** | ***P*** | **ηp2** |
| REI 10 R | 3.69 | 2,45 | 0.033 | 0.14 |
| REI 10 E | 1.51 | 2,45 | 0.233 | 0.06 |
| AOT | 3.02 | 2,45 | 0.060 | 0.12 |
| NART | 2.48 | 2,45 | 0.100 | 0.25 |

*Abbreviations: Rational Experiential Inventory 10 R (rational sub-scale), E (experiential sub-scale), Actively Open-minded Thinking (AOT) scale, National Adult Reading Test (NART) and degrees of freedom (df).*

Multiple pairwise comparisons revealed that REI 10 R scores were significantly higher for Group 3 (the sham group) (M = 19.80, SD = 3.61) compared to Group 2 (M = 15.90, SD = 4.84) *p* = 0.03, but not compared to Group 1 (M = 16.80, SD = 4.84) *p* = 0.12, 95% CI [-6.01, 0.01]. Since the direction of this difference is opposite to our hypothesis (as REI-R scores positively correlate with CRT scores, see Broyd et al., 2019) higher REI-R scores for Sham group would mean higher assumed CRT scores for this baseline condition, hence make a comparison with the stimulation group more conservative.

A further analysis of differences between experimental groups examined impulsivity as measured by the Barratt Impulsiveness Scale (BIS). A MANOVA was performed with stimulation as the between-subject factor. Dependent variables were the Barratt Impulsiveness Scale (BIS) second order subscales: attentional impulsiveness, motor impulsiveness and non-planning impulsiveness. The Box’s test results showed equality of covariance matrices (*p* = 0.86). The MANOVA revealed that the BIS impulsivity subscale scores did not differ significantly between groups, Wilks’ Lambda = 0.93, *p > 0.73* (Supplementary Table 3).

**Supplementary material**

**Part I – Questionnaires and Scales**

***Verbal CRT***

***Sirota, (2017)***

1. How many animals of each sex did Moses take on the ark?
*(Intuitive answer 2; correct answer None, according to mythology Noah did).*
2. A monkey, a squirrel, and a bird are racing to the top of a coconut tree. Who will get the banana first, the monkey, the squirrel, or the bird? *(Intuitive answer monkey or bird; correct answer none, it is a coconut tree).*
3. In a one-story pink house, there was a pink person, a pink cat, a pink fish, a pink computer, a pink chair, a pink table, a pink telephone, a pink shower - everything was pink! What colour were the stairs probably?
*(Intuitive answer pink; correct answer there are no stairs).*
4. The wind blows west. An electric train runs east. In which cardinal direction does the smoke from the locomotive blow? *(Intuitive answer east or west; correct answer there is not smoke it is an electric train).*
5. If you have only one match and you walk into a dark room where there is an oil lamp, a newspaper and wood - which thing would you light first? *(Intuitive answer the lamp; correct answer the match).*
6. It's a stormy night and a plane takes off from JFK airport in New York. The storm worsens, and the plane crashes - half lands in the United States, the other half lands in Canada. In which country do you bury the survivors? *(Intuitive answer the United States or Canada; correct answer they are survivors, you don’t bury them).*
7. Would it be ethical for a man to marry the sister of his widow? *(Intuitive answer yes or no; correct answer he cannot he is dead)*
8. Which sentence is correct: a) “the yolk of the egg are white” or b) “the yolk of the egg is white”? *(Intuitive answer b; correct answer neither).*
9. Mary’s father has four daughters: Nini, Nene, Nana, Nono? What is the name of the 5th daughter? *(Intuitive answer Nunu; correct answer Mary).*
10. You are participating in a race. You overtake the second person. What position are you in?

*(Intuitive answer 1st; correct answer 2nd).*

***Thomson & Oppenheimer, (2016) (used in verbal-CRT)***

1. Emily’s father had three daughters. The first two are named April and May. What is the third daughter’s name? *(Intuitive answer June; correct answer Emily). \*\*\*\* Note that this was not used in the same session as number 9 above.*
2. A clerk in the butcher ship is 5’ 10’’ tall. What does he weigh? *(Intuitive answer: I don’t know, Correct answer: meat)*

**(Numerical) Cognitive Reflection Test**

***Frederick, (2005)***

1. A bat and a ball cost £1.10 in total. The bat costs a pound more than the ball. How much does the ball cost?

*(Intuitive answer 10 pence; correct answer 5 pence).*

1. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?

*(Intuitive answer 100 minutes; correct answer 5 minutes).*

In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half the lake?

*(Intuitive answer 24 days; correct answer 47 days).*

***Toplak (2014)***

1. If John can drink one barrel of water in 6 days, and Mary can drink one barrel of water in 12 days, how long would it take them to drink one barrel of water together? *(Intuitive answer 9; correct answer 4).*
2. A man buys a pig for £60, sells it for £70, buys it back for £80, and sells it finally for £90. How much has he made? *(Intuitive answer £10; correct answer £20).*
3. Simon decided to invest £8,000 in the stock market one day early in 2008. Six months after he invested, on July 17, the stocks he had purchased were down 50%. Fortunately for Simon, from July 17 to October 17, the stocks he had purchased went up 75%. At this point, Simon has:

a. broken even in the stock market.
b. is ahead of where he began.
c. has lost money.
*(Intuitive answer b; correct answer c value is £7000).*

1. Jerry received both the 15th highest and the 15th lowest mark in the class. How many students are in the class?
*(Intuitive answer 30; correct answer 29).*

***Thomson & Oppenheimer, (2016)***

1. If you’re running a race and you pass the person in second place, what place are you in? *(Intuitive answer 1st; correct answer 2nd).*
2. A farmer had 15 sheep and all but 8 died. How many are left? *(Intuitive answer 7; correct answer 8).*
3. How many cubic feet of dirt are there in a hole that 3’ deep x 3’ wide x 3’ long? *(Intuitive answer 27; correct answer none – no dirt).*

***Tremoliere & De Neys (2014)***

1. A Ferrari and a Ford together cost £190,000. The Ferrari costs £100,000 more than the Ford. How much does the Ford cost?
*(Intuitive answer $90,000: correct answer $45,000)*

***Primi et al., (2017)***

1. If three elves can wrap three toys in an hour, how many elves are needed to wrap six toys in 2 hours? *(Intuitive answer 6 elves: correct answer 3 elves)*
2. In an athletics team, tall members are three times more likely to win a medal than short members. This year the team had won 60 medals so far. How many of these have been won by short athletes? *(Intuitive answer 20 medals; correct answer 15 medals)*

***Ackerman (2014)***

1. A frog fell into a hole 30 meters deep. Every day it climbs up 3m, but during the night it slides 2m back down. How many days will it take the frog to climb out of the hole? *(Intuitive answer 30 days; correct answer 28 days)*
2. Apple mash is comprised of 99% water and 1% apple solids. I left 100 kg mash in the sun and some of the water evaporated. Now the water is 98% of the mash. What is the mash weight? *(Intuitive answer 99; correct answer 50)*
3. If a test to detect a disease whose prevalence is 1/1000 has a false positive rate of 5% what is the chance that a person found to have a positive result actually has the disease, assuming that you know nothing about the person’s signs or symptoms? *(Intuitive answer 95; correct answer 2)*
4. Every day, a bakery sells 400 cookies. When the manager is not there, 20% of the cookies made that day are eaten by the staff. How many additional cookies should be made on the manager’s day off to ensure that 400 cookies can be sold? *(Intuitive answers 80, 500; correct answers 100)*
5. Steve was standing in a long line. To amuse himself he counted the people waiting, and saw that he stood 38th from the beginning and 56th from the end of the line. How many people are stood in the line? *(Intuitive answers 94 or 92; correct answers 93)*
6. Ants are walking in a line. A bad-mannered ant cuts in front of the ant walking second. What is the rude ant’s place in the line?
*(Intuitive answer 1st; correct answers 2nd)*

***Szaszi et al (2017)***

1. In which decade did the Beatles become the most popular American band ever? *(Intuitive answer 1960s: correct answer they were not American)*

**Incongruent base-rate (representativeness)**

1. Among a sample of 900 people there were 810 farmers and 90 illustrators. James is a randomly chosen participant. James is meticulous, has a strong eye for detail, enjoys listening to music whilst working and has a creative trait.

What is most likely?
a. James is an illustrator.

b. James is a farmer.

2. At the supermarket there were 600 people. Among the shoppers there were 570 actresses and 30 librarians. Susan is a randomly chosen person from the supermarket. Susan is very shy and withdrawn, invariably helpful, but has little interest in people, or in the world of reality. A gentle and tidy soul, she has a need for order and structure and a passion for detail.

What is most likely?
a. Susan is an actress.

b. Susan is a librarian.

3. In a study 1000 people were tested. Among the participants there were 992 musicians and 8 retail managers. Colin is as randomly chosen participant of this study. Colin is a meticulous time keeper, makes notes of everything, keeps a diary, is charismatic and always plans his day ahead.

What is most likely?
a. Colin is a musician.
b. Colin is a retail manager.

4. A survey of 1500 people was conducted. Among the participants in the survey there were 11 sixteen-year olds and 1489 fifty-year olds. Ellen is a randomly chosen participant of this survey. Ellen likes to listen to hip hop and rap music. She enjoys wearing tight shirts and jeans. She’s fond of dancing and has a small nose piercing.

What is most likely?
a. Ellen is sixteen years old.

 b. Ellen is fifty years old.

5. In a study 1000 people were tested. Among the participants there were 4 whose favourite television series is Star Trek and 996 whose favourite series is Eastenders. Jeremy is a randomly chosen participant of this study. Jeremy is 26 and is doing graduate studies in physics. He stays at home most of the time and likes to play video-games.

What is most likely?
a. Jeremy’s favourite television series is Star Trek
b. Jeremy’s favourite television series is Eastenders.

6. In a study of 1000 people there were 5 engineers and 995 lawyers. Jack is a randomly chosen participant of this study. Jack is 36 years old. He is not married and is somewhat introverted. He likes to spend his free time reading science fiction and writing computer programmes.

What is most likely?
a. Jack is an engineer.

b. Jack is a lawyer.

7. 1200 people were tested. Among the participants there were three who live in a condo and 1197 who live in a farmhouse. Kurt is a randomly chosen participant of this study. Kurt works in Canary Wharf and is single. He works long hours and wears Amani suits to work. He likes wearing shades.

What is most likely?
a. Kurt lives in a condo.
b. Kurt lives in a farmhouse.

8. In a nightclub there are 700 people. Among the clubbers there were 4 men and 696 women. Sam is a randomly chosen person from this nightclub. Sam is 23 years old and is finishing a degree in engineering. On Friday nights, Sam like to go out cruising with friends whilst listening to loud music and drinking beer.

What is most likely?

a. Sam is a man.
b. Sam is a woman.

9. In a shopping centre there were 1600 people. Among the people in the shopping centre there were 1595 who buy their clothes in Primark and 5 who buy their clothes at high-end retailers. Karen is a 33-year-old female. She works in a business office and drives a Porsche. She lives in a fancy penthouse with her boyfriend.

What is most likely?
a. Karen buys her clothes at a high-end retailer.

b. Karen buys her clothes at Primark.

10. In a study, 1000 people were tested. Among the participants there were 3 who have a tattoo and 997 without a tattoo. Jay is a randomly chosen participant of this study. Jay is a 29-year-old male. He has served a short time in prison. He has been living on his own for 2 years now. He has an older car and listens to punk music.

What is most likely?

a. Jay has a tattoo.

b. Jay has no tattoo.

11. In a study of 1000 people there were 996 executive managers and 4 kindergarten teachers. Lilly is a randomly chosen participant of this study. Lilly is 37 years old. She is married and has 3 children. Her husband is a veterinarian. She is committed to her family and always watcher the daily cartoon shows with her children.

What is most likely?
a. Lilly is a kindergarten teacher

b. Lilly is an executive manager

12. In a study of 1000 people there were 996 Bruce Springsteen fans and 4 Britany Spears fans. Tare was randomly chosen for this study. Tara is 15. She loves to go shopping at the mall and to talk with her friends about their crushes at school.

What is most likely?
a. Tara is a Bruce Springsteen fan.

b. Tara is a Britany Spears fan.

13. In a study there were 1000 people, there were 995 Americans and 5 French people. Martine is a randomly chosen participant of this study. Martine is 26-years- old. She is bilingual and reads a lot in her spare time. She is a very fashionable dresser and a great cook.

What is most likely?
a. Martine is American.

b. Martine is French.

14. In a study of 1000 people there were 100 Italians and 900 Swedish participants. Marco has been selected at random for the study. Marco is 16-years-old. He loves to play football with his friends, after which they go out for pizza or to someone’s house for homemade pizza.

What is most likely?

a. Marco is Italian.

b. Marco is Swedish.

15. In a study there were 1000 people in a room. There were 900 forty-year old participants and 100 seventeen-year old participants. Ryan is a randomly selected participant of this study. Ryan lives in Guildford. He hangs out with his buddies every day and likes watching MTV. He is a big fan of Green Day and is saving to buy his own car.

What is most likely?
a. Ryan is 40-years-old.

b. Ryan is 17-years-old.

16. In a study there were 1000 people. There were 150 architects and 850 taxi drivers. Steven is a randomly chosen participants of this study. Steven is very shy and withdrawn, invariably helpful, but with little interest in people, or in the world of reality. A meek and tidy soul, he had a need for order and structure, and a passion for detail.

What is most likely?
a. Steven is an architect.

b. Steven is a taxi driver.

17. In a university there were 1000 people. There 175 students of beauty therapy and 825 students of chemistry. Sarah is a randomly selected student from the 1000 people. Sarah loves to listen to new age music and faithfully reads her horoscope each day. In her spare time, she enjoys aromatherapy and attending a local spirituality group.

What is most likely?
a. Sarah is a student of beauty therapy.

b. Sarah is a student of chemistry.

18. In a group there are 800 people. There are 640 social science students and 160 engineering students. Tom was randomly selected from this group. Tom is highly intelligent, although lacking in true creativity. He has a need for order and clarity, and for neat and tidy systems in which every detail finds its appropriate place. His writing is rather dull and mechanical.

What is most likely?
a. Tom is a student of engineering.

b. Tom is a student of social science.

19. In study of 1000 people were tested. Among the participants there were 992 musicians and 8 retail managers. David is as randomly chosen participant of this study. David is a meticulous time keeper, makes notes of everything, keeps a diary, is charismatic and always plans his day ahead.

What is most likely?
a. David is a musician.
b. David is a retail manager.

20. In a study of 700 people there were 85 television reporters and 615 builders. Ray is a randomly chosen participant of this study. Ray always dresses smartly, liking to wear a suit. He keeps up-to-date with current affairs and speaks very clearly.

What is most likely?

a. Ray is a builder

b. Ray is a television reporter