RESTING-STATE NETWORKS AND THEIR RELATION TO PERFORMANCE ON MENTAL ATTENTION CAPACITY TASKS

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Abstract

Mental attention capacity (M-capacity) refers to an individual's limited cognitive capacity to hold and manipulate a set of task-relevant information, a function related to working memory. This study analyzes the within- and cross-network resting-state functional connectivity (RSFC) of the default mode network (DMN), the dorsal attention network (DAN), and the frontoparietal control network (FPC) in order to determine if they are related to high versus low performance on varying difficulty levels of mental attention tasks. I hypothesized that, relative to the Low Performance Group, the High Performance Group would have stronger RSFC within-networks, higher anticorrelation or RSFC between the DMN and DAN, and weaker RSFC between the FPC and the DMN. There were no significant differences between the groups to support the hypotheses, however marginally significant trends do support the hypothesis that the High Performance Group has weaker RSFC between the FPC and DAN than the Low Performance Group.

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List of Abbreviations

M-Capacity	Mental Attention Capacity
RSFC	Resting-State Functional Connectivity
DMN	Default Mode Network
DAN	Dorsal Attention Network
FPC	Frontoparietal Control Network
fMRI	Functional Magnetic Resonance Imaging
BOLD	Blood-Oxygenated-Level-Difference
RSN	Resting-State Network
MPFC	Medial Prefrontal Cortex
PCC	Posterior Cingulate Cortex
pIPL	Posterior Inferior Parietal Lobule
DLPFC	Dorsolateral Prefrontal Cortex
FEF	Frontal Eye Fields
iPCS	Inferior Precentral Sulcus
MT+	Middle Temporal Motion Complex
SPL	Superior Parietal Lobule
RLPFC	Rostrolateral Prefrontal Cortex
MFG	Middle Frontal Gyrus
aIFO	Anterior Insula/Frontal Operculum
dACC	Dorsal Anterior Cingulate Cortex
Pcu	Precuneus
aIPL	Anterior Inferior Parietal Lobule
PHC	Parahippocampal Cortex
TR	Repetition Time
TE	Echo Time
FA	Flip Angle
EPI	Echo-Planar Imaging
FOV	Field of View
CMT	Colour-Matching Task
FIT	Figural Intersection Task
ME-ICA	Multi-Echo Independent Component Analysis
MNI	Montreal Neurological Institute
FWHM	Full Width at Half Maximum
AFNI	Analysis of Functional NeuroImages
ROI	Regions of Interest
ANOVA	Analysis of Variance
FDR	False Discovery Rate

Resting-State Networks

Functional magnetic resonance imaging (fMRI) techniques have provided abundant insight into the functioning of the brain. Resting-state functional connectivity (RSFC) analysis measures the covariance of low-frequency fluctuations in blood-oxygenated-level-difference (BOLD) signal while the subject is at rest. In recent years, studying RSFC has been a useful method of understanding brain organization and function. Biswal and colleagues (1995) demonstrated that the seemingly random brain activity seen at rest was temporally correlated among brain regions within functional networks. What was originally thought of as random noise has proven to contain valuable information about brain function. Functional connectivity is considered an indicator of the degree of functional relatedness between brain regions.

Researchers have identified many large scale neural networks, however this study will focus on three specific, well-characterized resting-state networks (RSN) that are thought to have significant inter-dependent roles in memory and cognition: the default mode network (DMN), the dorsal attention network (DAN), and the frontoparietal control network (FPC). The DMN is associated with internally focused cognition (Spreng et al., 2010), including memory retrieval, self-evaluation, and behavioural planning (Damoiseaux et al., 2006). These are cognitive tasks that are usually suppressed while performing externally focused attention tasks (Andrews-Hanna et al., 2014). The DMN consists of the medial prefrontal cortex (MPFC), the posterior cingulate cortex (PCC), the lateral and medial temporal lobes, and the posterior inferior parietal lobule (pIPL), among other regions (Spreng et al., 2010). The DAN is associated with externally focused cognition like orienting to external stimuli (Corbetta and Shulman 2002; Fox et al, 2006). Activity within this network is anticorrelated with the activity of the DMN (Fox et al., 2005). The DAN consists of the dorsolateral prefrontal cortex (DLPFC), the frontal eye fields (FEF), inferior precentral sulcus (iPCS), middle temporal motion complex (MT+), and the superior parietal lobule (SPL), among other regions (Fox et al., 2005). Finally, the FPC guides goal-directed cognition through dynamic coupling and decoupling with the DMN and DAN supporting internal versus external cognition, respectively (Spreng et al., 2010). This network consists of the rostrolateral prefrontal cortex (RLPFC), middle frontal gyrus (MFG), anterior insula/frontal operculum (aIfO), dorsal anterior cingulate cortex (dACC), precuneus (Pcu), and anterior inferior parietal lobule (aIPL), among other regions (Vincent et al., 2008).

Widespread research on RSFC has shown that activity within and across these networks is implicated in a large variety of behavioural functions (Mueller et al., 2013). Research has shown that recent experiences can modulate RSFC within these RSNs. In a study conducted by Albert and colleagues (2009), participants were divided into two groups, a practice group and a control group, prior to completing a motor skills task. Baseline RSFC was recorded for both groups. The practice group then practiced a task-relevant motor skills task while the control group conducted a similar but irrelevant motor task. RSFC was recorded a second time and compared to baseline RSFC. Unique to the practice group was a post-task increase in the strength of connectivity within frontoparietal brain regions, indicating that the recent experience modulated RSFC. Studies across many behavioural domains have found similar effects. As discussed below, subsequent studies by various researchers have provided evidence that these RSFC changes have a functional role in cognition and are not merely an epiphenomenon due to a recent experience.

RSNs and Behavioural Performance

Substantial research suggests that RSFC within and/or across RSNs affects future behaviours (e.g., memory and learning). For example, Stevens and colleagues (2010) demonstrated that the magnitude of the temporal correlation of BOLD signal fluctuations (i.e., RSFC) between the right inferior frontal gyrus and scene-preferential parahippocampal cortex (PHC) increased during rest following performance of a scene categorization task, and that the degree of this increase predicted subsequent scene recognition. Another brain-behaviour analysis conducted by Hampson and colleagues (2006) revealed that performance on a 3-back, block-design, working memory task was significantly positively correlated with the strength of RSFC between the MPFC and the PCC.

Degradation of RSNs and Behavioural Performance

Research indicates that alterations in RSFC among regions of the DMN may be a characteristic of cognitive impairment and dementia (Rombouts et al., 2005), as well as a reflection of the cognitive deficits associated with aging (Sambataro et al., 2010). Grady and colleagues (2006) investigated the mechanisms involved in the changes in memory that occur with age. Using fMRI they examined brain activity during encoding and recognition tasks. They found age-related increases in BOLD activity in brain regions traditionally deactivated during task (e.g., medial frontal and parietal regions) and decreases in BOLD activity in brain regions traditionally activated during task. Research conducted by Sambataro and colleagues (2010) related the differences in RSFC seen in older versus young adults to their differences in working memory performance. Older adults showed decreases in DMN suppression during task and decreases in DMN functional connectivity at rest, and performed worse on an N-back working memory task than the young adults who did not display this RSFC pattern. Specifically, they found that functional coupling between the PCC and MPFC in the DMN was positively correlated with performance in a working memory task. Older adults, who performed significantly worse on the working memory tasks than the young adults not only showed a decrease in the strength of the RSFC between the PCC and MPFC, they also had a higher activation of these brain regions during task than the young adults.

There is substantial research that focuses on the role of the DMN in poorer memory performance, specifically the lack of deactivation in this network during task (e.g., Grady et al., 2006; Miller et al., 2008). Spreng and colleagues (2016) furthered this research by comparing both task-related functional connectivity and RSFC within and across the DMN and the DAN in young and older adults. They found weaker RSFC within both the DMN and DAN, and weaker anticorrelation of activity across these networks (i.e., reduced suppression) during both task and rest in the older adults relative to the young adults. During an autobiographical planning task (i.e., internally focused cognition), MPFC activity was positively correlated with that of other regions of the DMN, and anticorrelated with activity in DAN regions in the young adults. In the older adults, however, MPFC activity was correlated with activity in regions of both the DMN and the DAN (e.g., FEF, IPS, SPL, DLPFC). Similarly, during rest, both the MPFC and PCC had stronger RSFC with other areas of the DMN in young adults than in older adults, and young adults showed anticorrelations between the DMN and DAN whereas older adults showed some correlation between these two networks.

FPC and Behavioural Performance

Spreng and colleagues (2010) discussed the importance of the FPC on performance of cognitive tasks. The FPC is thought to be responsible for cross internal-external domain cognition through coupling or decoupling with the DMN or DAN. For example, as Spreng and colleagues (2010) noted, planning for one's future requires both internally focused cognition (DMN activation), and externally focused cognition (DAN activation). The FPC allows these tasks, which seem inherently contradictory due to the nature of their anticorrelated networks, to be achieved by acting as a switch, co-activating with the DMN or DAN.

The FPC is a critical factor in subsequent behavioural performance. Grady and colleagues (2016) demonstrated that stronger FPC cross-network RSFC predicts better associative memory performance, regardless of age. However, this increase in RSFC is more pronounced in older adults. Additionally, they found that an increase in RSFC between the FPC and DMN predicted reduced RSFC within the DMN (a signature pattern in older adults which relates to poorer task performance). They suggested that this increase in cross-network RSFC could be a compensation mechanism employed by older adults to mitigate the effects caused from their reduced within-network RSFC (Grady et al., 2016).

Turner and Spreng (2015) proposed the Default-Executive Coupling Hypothesis of Aging (DECHA). This hypothesis posits that with increasing behavioural task demand, compared to young adults, older adults perform worse due a failure to modulate activation and suppression of the DMN and executive network appropriately. Greater coupling of DMN and the lateral prefrontal cortex of the FPC during task is seen in older adults than in young adults due to a failure of the DMN to decouple from the lateral prefrontal cortex, and the DMN is less suppressed during task in older adults. Turner and Spreng postulate that these functional changes reflect the shift seen in older adults who rely more on crystalized cognition rather than fluid cognition to perform goal-directed tasks. In 2018, Spreng and colleagues tested their DECHA model using RSFC analysis and found consistent results; there was stronger coupling of the DMN and executive regions as well as reduced RSFC within the DMN in the older group than in the younger group.

Similar to the DECHA findings, Keller and colleagues (2015) examined young adults and found that greater RSFC between the DMN and FPC was associated with lower working memory capacity. Franzmeier and colleagues (2017) studied mild cognitive impairment in older adults and found that those who had stronger RSFC between the FPC and DMN had reduced cognitive reserves. We see this pattern of FPC and DMN in a variety of studies, all concluding that stronger coupling of the FPC and DMN results in worse memory.

Genetics and RSNs

While there is much evidence that changes in RSFC are experience dependent, there is also research indicating that, to some extent, RSFC is genetically determined (Stevens & Spreng, 2014). For example, a study conducted by Adelstein and colleagues (2011) showed that RSFC within areas of the brain associated with each of the big five personality traits had reliable correlations with behavioural measures of these traits.

Mental Attention Capacity and RSNs

We know that RSFC can provide information about, and predict, subsequent behaviour including memory performance, as discussed above. Therefore, our knowledge regarding RSFC and its effects on subsequent behaviour is relevant to a related construct, mental attention capacity (M-capacity).

M-capacity and The Theory of Constructive Operators

Dr. Juan Pascaul-Leone developed the Theory of Constructive Operators (TCO: Pascual-Leone, 1995). The TCO quantitatively explains Piaget's qualitative stage theory of cognitive development. The TCO introduced the concept of M-capacity, which refers to an individual's limited cognitive capacity to hold and manipulate a set of task-relevant information. M-capacity requires the acknowledgment of the load on M-capacity, or "M-demand", which is the number of units of relevant information, while incorporating a construct called an I-operator[1] (Arsalidou et al., 2010). An I-operator is a function that is applied to any given information that is deemed irrelevant in a certain context in order to inhibit that information. M-capacity is measured in total number of units of task-relevant information being held in memory (M-demand), while considering the number of units of task-irrelevant information provided (I-operator). M-capacity is an operationalized and measurable construct that is implicated in the

[1] An operator refers to a content free function that is applied to a scheme. A scheme is defined as a structure that determines particular actions or cognitions (Chapman, 1981).

development of intelligence (Pascual-Leone & Johnson, 2005). The ability to hold a large number of task-relevant elements in memory is crucial for difficult problem-solving tasks. As M-capacity increases, as it does during typical human development, cognitive functioning improves (Pennings & Hessels, 1996). M-capacity has a linear developmental trajectory of a one-unit increase every two years between the ages of three and 16, when the average M-capacity is seven (Pascual-Leone & Johnson, 2005; Arsalidou et al., 2010).

Objective

This study investigates the three RSNs discussed above (the DMN, DAN, and FPC) to determine their relationship to M-capacity. Specifically, the objective of this study is to analyze both within- and cross-network RSFC to determine if they are related to performance on M-capacity tasks. This research will enhance our understanding of the relationship of these RSNs with M-capacity performance. M-capacity is thought to play a crucial role in the development of intelligence; therefore, the ability to gain insight into M-capacity through RSFC analyses may significantly further our understanding of cognitive processes and intellectual development.

Hypotheses

I hypothesized that individuals who perform better on the M-capacity tasks will have (1) stronger RSFC among regions within the DMN; (2) stronger RSFC among regions within the DAN; (3) stronger RSFC among regions within the FPC; (4) stronger anticorrelation of RSFC between the DMN and DAN; and (5) weaker cross-network correlation between the DMN and FPC.

Methods

Participants

Data were collected from a total of 30 healthy participants (16 female) between the ages of 20 and 30 (*Mean age* = 23, *SD* = 2.85), who were recruited through posters and word of mouth. Ethical approval for this study was provided by York University Human Participants Review Sub-Committee, and informed consent was obtained from all participants. The exclusionary criteria for this study were diagnosed neurological disorders, brain injuries, left handedness, abnormal vision that cannot be corrected with basic lenses, non-proficiency with the English language, colour blindness, and any condition that made the participant incompatible with the MRI environment. Visual acuity and colour-vision were self-reported, however, during the practice tasks described below, research assistants checked that participants were able to distinguish between all of the colours involved in the task. Participants with corrective glasses were provided with MRI-compatible glasses during scanning.

Materials and Apparatus

MRI Simulator

All participants were exposed to practice trials in an MRI simulator prior to being scanned in order to replicate the experience of a real MRI scanner. This was done in order to reduce noise in the MRI data through habituating participants to the MRI scanner environment and sounds, and by training participants to reduce head movement through a movement-feedback protocol.

MRI Data Acquisition

Participants were scanned in a 3T Siemens Magnetom Tim Trio scanner using a 32-channel head coil at the York MRI facility. 10-min resting-state runs (data collected while participants were not engaged in any task) were collected for each participant prior to completing the M-capacity tasks in the scanner. The anatomical images were acquired with a 3D magnetization prepared rapid gradient echo sequence (repetition time [TR] = 2300 ms, echo time [TE] = 2.62 ms; flip angle [FA] =9°; 1.0 mm isotropic voxels). Rest-runs were acquired using a multi-echo echo-planar imaging (EPI) sequence with the following parameters: TR = 2620 ms, TE = 14, 27, and 40 ms; FA = 83°; field of view (FOV) = 216 mm; 229 measurements per run; voxel size = 3.4 × 3.4 × 3.0 mm; 43 interleaved slices covering the whole brain, including the cerebellum. Task-runs were scanned using BOLD functional scanning with the following parameters: TR = 2500 ms; TE = 30 ms; FA =83°; FOV= 240 mm; 132 measurements per run; voxel size = 3.0 mm isotropic voxels; 41 interleaved slices covering the whole brain, including the cerebellum.

Behavioural Tasks

There were several M-capacity tasks conducted, some while in the MRI scanner and some outside of it. However, this study will only focus on two of the tasks: the colour matching task (CMT) with a clown stimulus (CMT-Clown), which was conducted while participants were in the MRI scanner, and the figural intersections task (FIT), which was a pen and paper task conducted outside of the scanner. These tasks were analyzed in this study as they are considered to be a “misleading tasks” (i.e., they include distracting information that must be suppressed) and are therefore thought to most authentically measure M-capacity as it engages the I-operator (Arsalidou et al., 2010).

The premise of the CMT-clown task is that certain aspects of the stimulus were to be ignored while others were to be remembered. This task was a 1-back working memory test. It required participants to make a same-or-different judgment about a stimulus by comparing it to the immediately preceding stimulus. Images were continuously presented for 3 s at a time with a 1-s interval between images. Thus, a stimulus that a participant just made a judgment on (by comparing it to a previous stimulus) became the stimulus to which the next stimulus was compared. This task had specific rules that had to be applied when making judgments as to whether the stimuli were the same or different. The colours blue and green, as well as any colour on the clown’s face were to be ignored. Any other colour on the clown was to be remembered, regardless of the location and number of elements of a given colour, and same-or-different judgments were made about this specific set of colours (Figure 1). Some trials consisted of comparing stimuli without any colours of interest (i.e., all blue and/or green) – these were control stimuli used to assess baseline brain activity measures of perceiving the image and responding.

Same-or-different judgments were indicated by participants and recorded via a right-handed button box with a total of four buttons. Participants pressed the first button with their index finger in order to indicate that the stimulus was the same as the previous stimulus, or the second button with their middle finger to indicate that the stimulus was different from the previous stimulus. Participants were also instructed to press the third button with their ring finger if they were unable to make a comparison (e.g., during control trials, when stimuli only contained irrelevant information). The purpose of this third button was to match the BOLD signal associated with pressing buttons during the control trials and trials of interest.

There were six difficulty levels in this experiment. Level of difficulty was manipulated by changing the number of relevant colours to be remembered. The CMT-Clown was a misleading task, as it had the clown's face as a distractor, thus the difficulty level for this task was determined through the calculation n + 2, where n is the number of relevant colours and 2 represents the level of executive demand (colour changing and distracting element of the clown's face).

The FIT is a pen and paper task that has been validated as a measure of M-capacity (Pascual-Leone & Baillargeon, 1994). Participants are presented with a group of discrete shapes on the right-hand side of the page, with an image of overlapping shapes on the left-hand side. The participant is instructed to indicate where, on the left side, all of the shapes from the right side intersect, regardless of the size and rotation of the shapes (Figure 2). The image on the left can also include irrelevant shapes (that are absent on the right side of the page) that must be ignored by the participant. The difficulty of each trial is indexed by the number of shapes of interest and the presence of irrelevant shapes. (For a detailed description of the FIT see Pascual-Leone & Baillargeon, 1994).

Procedure

Practice Tasks

Before participating in the task, participants completed a practice version of that task whereby they were trained on shorter versions of the CMT. In the MRI simulator, participants underwent a motion tracking session, with head movement feedback, learning how to remain still in the MRI scanner. Next, the participants completed the shortened version of the CMT task, responding using the button box. The MRI simulator played audio recordings of actual MRI sequences in order to habituate participants to an MRI scanner.

Data Acquisition

One week after the practice session, participants returned to complete the actual experiment. Before entering the MRI scanner, instructions were repeated to the participants using a script. The scan began with the acquisition of 10 min of rest data. Next, the CMT task was administered. The task had four runs. Each run had seven blocks presented in counterbalanced order. One block was a control block containing only control stimuli. The other six blocks were assigned to each of the six difficulty levels. Each of the blocks had eight stimuli presented (a total of seven comparisons, as the first stimulus had no preceding comparison trial), totaling 56 stimuli per run, or 224 stimuli per task. Each stimulus was presented for 3 s with an inter-stimulus interval of 1 s. Each block concluded with a 1.5-s cue (a black "+" on a white background). Each run began with a 10-s fixation period (a black "X" on a white background, followed by a 2.5-s block onset cue, similar to the block conclusion cue). Combined, each task-run spanned 5 min and 24 s, where each block spanned 32 s. In total, each task took a total of 21 min and 36 s (Figure 3). After the session, participants were debriefed, paid $20.00 as compensation, and completed a post-task survey about the strategies they used during the tasks.

Behavioural Analysis

All behavioural task data were analyzed previously, with accuracy calculated for every individual at each difficulty level within each task. A given participant's M-capacity was defined as the highest level of difficulty that the individual passed on the CMT-Clown task with a minimum accuracy of 70% correct, as defined in previous protocols (Arsalidou et al., 2010; Arsalidou et al., 2013). If a participant failed one difficulty level but passed a higher difficulty level, their M-capacity was based on the highest level they passed, despite failing a lower level.

Due to the low variability in M-capacity scores, participants were dichotomized into two groups in order to compare individuals with high versus low M-capacity. For one set of analyses, the groups were determined based on performance on the CMT-Clown task, and for a second set of analyses, the groups were determined based on performance on the FIT. The CMT-Clown task dichotomization was based on a median split. Coincidently, half of the participants scored perfectly (6/6), so the High Performance Group consisted of individuals who, according to the TCO, achieved their age-appropriate M-capacity score and the Low Performance Group consisted of individuals who did not achieve their age-appropriate M-capacity score. This same definition of age-appropriate versus below-age-appropriate scores was used to divide the participants based on their FIT scores for the second set of analyses (see Table 1 for descriptive statistics).

Preprocessing of RSFC

All participants' resting-state data were preprocessed using multi-echo independent component analysis (ME-ICA) with AFNI software (Cox, 1996). Single-echo fMRI pulse sequences are limited in their utility as it is difficult to distinguish between signal caused by noise (e.g., respiration) and true BOLD signal from neuronal activity. Several techniques to remove noise are used for single-echo data, but these techniques are limited as they do not adequately differentiate signal of interest from noise.

Because the data were acquired using multi-echo fMRI pulse sequences, I was able to take advantage of the ME-ICA preprocessing technique (Kundu et al., 2012), which effectively differentiates BOLD signal from noise in the rest data. This method included several standard preprocessing steps (de-spiking, slice-time correction, motion correction, registration to a standard Montreal Neurological Institute (MNI) atlas, and 4 mm FWHM Gaussian smoothing), as well as an ICA which identified components where the BOLD signal changes were associated with transverse relaxation rates (true BOLD) or with noise. This allowed for the identification and then removal of artifactual fluctuations in the BOLD signal. ME-ICA used these non-BOLD components as nuisance regressors, instead of using external nuisance regressors as in single-echo fMRI preprocessing. ME-ICA identified BOLD and non-BOLD components through examining the signal across echo times (TE_n). TE_n is a function of S_0 (initial signal intensity when TE = 0), which is considered noise, and R_2* (Relaxation rate, 1/T_2*), which is considered BOLD signal. Because multiple echo images are acquired for each slice, T_2* (relaxation time) decay can be modelled at every voxel at every time point, allowing for the examination of BOLD signal. Changes from the mean R_2* and S_0 that underlie signal fluctuations were estimated and used to determine which components were primarily BOLD or primarily noise. Data were also detrended to control for scanner drift and smoothed to alleviate additional noise.

Finally, a quality control was conducted. Head motion was visually inspected using AFNI's 1dplot. One participant was removed from the analyses due to excessive head motion. The functional time-series and anatomical images were inspected for spatial alignment. The number of components identified as BOLD signal was inspected to ensure that the data were not too noisy to be properly processed. Lastly, the identified components were visually inspected for artifacts.

Statistical Analyses

Regions of interests (ROI) within the DMN, DAN, and FPC were chosen based on coordinates reported in Yeo et al. (2011), who derived these coordinates from resting-state fMRI scans of 1000 participants. They registered all participants using surface-based alignment and employed a clustering approach to identify networks of functionally coupled regions. This resulted in the creations of six ROIs for each of the three networks (Table 21).

Additionally, a second set of ROIs was analyzed, using task-based ROIs within each of these networks. The coordinates of these task-based ROIs were determined in a previous study using the same participants during task. A linear contrast was calculated based on the data from three M-capacity tasks to identify brain voxels showing increasing activation that was linearly and monotonically associated with increasing task difficulty level. The results from these analyses were clusterized with a minimum cluster size of 100 voxels, and thresholded to $q < 0.01$ in order to yield statistically significant clusters wherein activation either increased or decreased with task difficulty. Six major network-affiliated ROIs that belonged to the three RSNs of interest (DMN, DAN, and FPC) were chosen from peak activation sites within these statistically significant clusters. This resulted in two ROIs for each network (Table 3).

In order to extract RSFC information from the networks, ROI masks with 3 mm radii were created for each coordinate using the 3dUndump function in AFNI. All the ROI masks from the 18 coordinates defined by Yeo et al. (2011) were combined into a single file and all the task-based ROI masks were combined into a single file using the 3dcalc command in AFNI. The mean BOLD signal time-course across voxels within each ROI mask and its correlation with that of all the other ROIs were calculated using the 3dNetCorr function. These values were converted to Fisher's z-scores and contrasted between two groups (High Performers versus Low Performers) with analyses of variances (ANOVAs) using R software.

First, 3 separate 2 × 2 × 2 ANOVAs were conducted using CMT-Clown scoring as the determinant of performance level. The analyses were then repeated using the FIT score as the determinant of performance level. Three ANOVAs were conducted in order to compare each pair of networks: DMN and DAN; DMN and FPC; and DAN and FPC.

Each ANOVA analyzed the differences between (1) the two level within-subject factor of network (e.g., DMN and DAN), (2) the two-level within-subject factor of differentiation (i.e., within-network RSFC versus cross-network RSFC) and (3) the two-level between-subjects factor of group (i.e., High Performance versus Low Performance).

The dependent variable in the ANOVAs was the RSFC within or across networks. For each network, the within-network RSFC was the average Fisher's z-score across all pairs of ROIs within the network. (With six ROIs, there were [6 × 5] ÷ 2 = 15 pairs of ROIs.) For each pair of networks, the cross-network RSFC was calculated in a similar way, as the average of 36 Fisher's z-scores. (With six ROIs in each network, there were [6 × 6] = 36 pairs of ROIs.) Therefore, each participant had one averaged Fisher's z-value for each network representing their within-network RSFC, and one averaged Fisher's z-value for each pair of cross-networks representing their cross-network RSFC. A Tukey's HSD was conducted to follow up on any significant findings from the ANOVAs. Similar analyses were conducted using the task-based ROIs.

Next, 6 separate 6 × 2 × 2 ANOVAs were conducted, using CMT-Clown scores as the performance group determinant. In these analyses, the three factors were (1) the six-level within-subjects factor of ROI (e.g., ROI 1 through ROI 6, for a given network, based on Yeo et al. (2011) coordinates); (2) the two-level within-subjects factor of differentiation; and (3) the two-level between-subject factor of group level. This 6 × 2 × 2 ANOVA structure was conducted six times in order to compare each node within each network's within-network RSFC versus its cross-network RSFC with another network. 6 ANOVAs are necessary in order to compare (1) the DMN's within-network RSFC versus its cross-network RSFC with the DAN and the FPC (two ANOVAs); (2) the DAN's within-network RSFC versus its cross-network RSFC with the DMN and the FPC (two ANOVAs); and the FPC's within-network RSFC versus its cross-network RSFC with the DMN and DAN (two ANOVAs). It is important to note that the analyses that compare, for example, DMN to FPC are not symmetric to the analyses that compare FPC to DMN. This is because the cross-network RSFC value associated with each ROI in the networks are calculated using different numbers. For example, the average cross-network RSFC value for the first ROI in the DMN is calculated by averaging the Fisher's z-values from the pairwise comparisons of that first ROI with each of the six ROIs in the FPC (an average of six values, in this case averaging 0.33). Similarly, the cross-network value for the second ROI in the DMN is calculated by averaging the pairwise correlation of that second ROI in the DMN with each of the six ROIs in the FPC. Conversely, the cross-network RSFC value for the first ROI in the FPC is calculated by averaging the Fisher's z-values from the pairwise comparison of that first FPC ROI with each of the six ROIs in the DMN (in this case averaging 0.35). The ROI within-network correlation is calculated by averaging the pairwise values of the ROI (e.g., ROI 1) with the five other ROIs in the network (e.g., 1-2, 1-3, 1-4, 1-5, 1-6). Tukey's HSD post-hoc analyses were conducted when statistically significant results occurred.

While all analyses thus far used dichotomized behavioural measures, a brain-behaviour correlation analysis examining CMT-Clown score on a continuous scale with each pairwise correlation of all 18 ROIs from the Yeo et al. (2011) coordinates was also conducted. A second brain-behaviour analysis was conducted to correlate each of the six task-based pairwise correlations with the CMT-Clown score and the FIT score on a continuous scale.

Next, correlation matrices for the High Performance and Low Performance Groups were created in order to provide a visual representation of the differences between pairwise correlations. Direct contrasts were made between the High Performance and Low Performance Groups using two-sample *t*-tests. This was conducted for both the literature-based ROIs and the task-based ROIs.

Finally, in order to fully explore the data, a seed-based whole-brain RSFC analysis was conducted. Participants in the High Performance and Low Performance Groups were analyzed separately. The mean time series from each task-based ROI was correlated with every other voxel of the brain to create whole-brain voxelwise RSFC maps. These Pearson's *r* correlation maps were converted to z-scores. Significance was determined using a false discovery rate (FDR) of $q < 0.05$. Differences between High and Low Performance Groups were directly contrasted with a two-sample *t*-test, using FDR correction to control for multiple comparisons. In order to explore trends in a more liberal way, I additionally explored the contrast maps without any correction for multiple comparisons ($p < 0.05$).

Results

RSFC within and between the DMN and DAN: literature-based coordinates

Group (High versus Low performance), network (DMN versus DAN), and differentiation (within-network versus cross-network) were the three factors in this ANOVA. The Fisher's z-score, representing the level of RSFC, was the dependent variable. This $2 \times 2 \times 2$ ANOVA yielded significant main effects exclusively. There was a significant difference between groups. The Low Performance Group had higher RSFC than the High Performance Group, $F(1,108) = 6.016$, $p = 0.0158$. As expected, there was also a significant effect of differentiation, where within-network RSFC was stronger than cross-network RSFC for both networks, $F(1,108) = 112.808$, $p < 0.001$ (Table 4).

RSFC within and between the DMN and FPC: literature-based coordinates

This ANOVA yielded significant main effects exclusively. There was a significant difference between groups. The Low Performance Group had higher RSFC than the High Performance Group, $F(1,108) = 8.790$, $p = 0.0037$. As expected, there was also a significant effect of differentiation, with within-network RSFC being stronger than cross-network RSFC for both networks, $F(1,108) = 38.657$, $p < 0.001$ (Table 5).

RSFC within and between the DAN and FPC: literature-based coordinates

This ANOVA yielded significant main effects, as well as one significant interaction effect. There was a significant difference between groups. The Low Performance Group had higher RSFC than the High Performance Group, $F(1,108) = 5.950$, $p = 0.0163$. As expected, there was also a significant effect of differentiation, with within-network RSFC being stronger than cross-network RSFC, $F(1,108) = 8.254$, $p = 0.0049$. Additionally, there was a main effect of network, where the DAN had significantly stronger RSFC than the FPC, $F(1,108) = 4.904$, $p = 0.0289$. Finally, there was an interaction between network and differentiation, $F(1,108) = 4.904$, $p = 0.0289$ (Table 6). This interaction effect was followed up with Tukey's HSD post-hoc test.

Tukey's HSD Post-Hoc Analysis for DAN to FPC Network-Differentiation Interaction: literature-based coordinates

Tukey's HSD post-hoc analysis revealed that the within-network RSFC of the DAN was significantly stronger than the cross-network RSFC of the DAN and FPC ($p = 0.0027$). However, the within-network RSFC of the FPC did not significantly differ from the cross-network RSFC of the DAN or FPC (Figure 4 & Table 7).

RSFC within and between individual ROIs within the DAN and FPC: literature-based coordinates

The goal of these analyses was to identify if there were any specific nodes within the DAN network (i.e., ROIs) that had significant effects that were perhaps masked at the network-wide level. There was a main effect of ROI, $F(5,324) = 2.484$, $p = 0.0316$, and similar to the DAN-FPC 2 × 2 × 2 ANOVA, there were significant main effects of differentiation, $F(1,324) = 59.026$, $p < 0.001$, and of group, $F(1,324) = 11.137$, $p < 0.001$. There were no interaction effects, thus no post-hoc analyses were conducted as these main effects were expected and were not of interest to this study (Table 8).

RSFC within and between individual ROIs within the FPC and DAN: literature-based coordinates

Similar to the DAN relative to FPC 6 × 2 × 2 ANOVA above, this analysis revealed a main effect of ROI, $F(5,324) = 6.871$, $p < 0.001$, and similar to the DAN-FPC 2 × 2 × 2 ANOVA, there was a significant main effect of group, $F(1,324) = 15.790$, $p < 0.001$ (Table 9). There were no interaction effects, thus no post-hoc analyses were conducted.

RSFC within and between individual ROIs within the DMN and FPC: literature-based coordinates

In this analyses we discovered that there were significant main effects of ROI, $F(5,324) = 6.691$, $p < 0.001$, of differentiation, $F(1,324) = 125.062$, $p < 0.001$, and of group, $F(1,324) = 22.090$, $p < 0.001$. There was a significant interaction effect of differentiation and ROI, $F(5,324) = 5.282$, $p < 0.001$ (Table 10), which was followed up with a Tukey's HSD post-hoc analysis.

Tukey's HSD Post-Hoc Analysis of DMN (to FPC) Network-Differentiation Interaction: literature-based coordinates

Figure 5 depicts what the Tukey's HSD post-hoc analysis revealed. Specific results can be seen in Table 11. Briefly, within-network RSFC of the DMN nodes was significantly stronger than cross-network (to FPC) RSFC, except for ROI 5, the PHC, for which there was no significant difference between within- and cross-network RSFC. The strength of within-network RSFC for ROIs 1-4 were stronger than the level of within-network connectivity at ROI 5. (See Table 3 for the brain regions associated with each ROI.)

RSFC within and between individual ROIs within the FPC and DMN: literature-based coordinates

This analysis also revealed significant main effects of ROI, $F(5,324) = 5.419$, $p < 0.001$, of differentiation, $F(1,324) = 53.329$, $p < 0.001$, and of group, $F(1,324) = 17.0133$, $p < 0.001$. There was a significant interaction effect of differentiation and ROI, $F(5,324) = 2.796$, $p < 0.001$ (Table 12), which was followed up with a Tukey's HSD post-hoc analysis.

Tukey's HSD Post-Hoc Analysis of FPC (to DMN) Network-Differentiation Interaction: literature-based coordinates

Figure 6 depicts what the Tukey's HSD post-hoc analysis revealed. Specific results can be seen in Table 13. Briefly, within-network RSFC of the FPC was significantly stronger than cross-network RSFC of the FPC to DMN for ROIs 13, 14, and 15, but there were no significant differences between within- and cross-network RSFC for ROIs 16, 17, and 18. (See Table 3 for brain regions associated with each ROI.)

RSFC within and between individual ROIs within the DMN and DAN: literature-based coordinates

In this analysis, there were significant main effects of differentiation, $F(1,324) = 228.829$, $p < 0.001$, and of group, $F(1,324) = 19.224$, $p < 0.001$. Additionally, there was a significant interaction effect of differentiation and ROI, $F(5,324) = 7.083$, $p < 0.001$ (Table 14), followed up with a Tukey's HSD post-hoc analysis.

Tukey's HSD Post-Hoc Analysis of DMN (to DAN) Network-Differentiation Interaction: literature-based coordinates.

Figure 7 depicts what the Tukey's HSD post-hoc analysis revealed. Specific results can be seen in Table 15. Briefly, within-network RSFC of the DMN was significantly stronger than cross-network RSFC, except the connectivity at ROI 5. At this point there were no significant differences within- and cross-networks. (See Table 3 for brain regions associated with each ROI.)

RSFC within and between individual ROIs within the DAN and DMN: literature-based coordinates

Finally, in this analysis, there were exclusively significant main effects of differentiation, $F(1,324) = 294.336$, $p < 0.001$, and of group, $F(1,324) = 8.295$, $p = 0.004$ (Table 16).

FIT scores

Identical analyses as the analyses discussed above were conducted using the FIT scores as the behavioural measure in place of CMT-Clown scores. Scores on the FIT and CMT-Clown had significant, but weak, correlation of 0.35 ($p < 0.05$).

The 2 × 2 × 2 ANOVAs comparing the DMN-FPC, DMN-DAN, and DAN-FPC yielded very similar results as the above analyses that used the CMT-Clown behavioural scores, however across all three analyses, there were no main effects of group when using the FIT scores.

RSFC within and between the DMN and DAN: FIT scores

As expected, there was a significant effect of differentiation, with within-network RSFC being stronger than cross-network RSFC, $F(1,100) = 97.933$, $p < 0.001$.

RSFC within and between the DMN and FPC: FIT scores

As expected, there was a significant effect of differentiation, with within-network RSFC being stronger than cross-network connectivity, $F(1,100) = 35.283$, $p < 0.001$.

RSFC within and between the DAN and FPC: FIT scores

As expected, there was a significant effect of differentiation, with within-network RSFC being stronger than cross-network connectivity, $F(1,100) = 7.027$, $p = 0.009$. There was also a significant main effect of network, $F(1,100) = 4.605$, $p = 0.03$, and a significant interaction effect of network and differentiation, $F(1,100) = 4.605$, $p = 0.03$.

No post-hoc analyses were conducted due to the similarity of results and their irrelevance to the hypotheses.

Brain-Behaviour Analysis: Correlating continuous M-capacity scores with pairwise RSFC:

A correlation analysis was conducted to determine if an individual's continuous M-capacity score (determined by CMT-Clown) was correlated with the pairwise RSFC for each of the 153 ROI pairs. These correlations ranged from -0.605 to 0.014, with 44% of pairwise RSFC values being significantly negatively correlated with M-capacity, $p < 0.05$, uncorrected. None of the ROI pairwise RSFC values were significantly positively correlated with M-capacity (Figure 8). The correlation matrix indicated that a larger proportion of the significant negative correlations were among cross-network pairwise correlations, and in particular across the DMN and DAN ROIs. This indicated that participants who scored lower on M-capacity had stronger pairwise RSFC, specifically across the DMN and DAN. Within each of the three RSNs, between 7 and 33 percent of the pairwise correlations were significantly negatively correlated with behavioural score. However, the percentage of significant negative pairwise correlations between the FPC and DMN and between the FPC and DAN were 39 and 36 percent, respectively, and the percentage of significant negative cross-network pairwise correlations across the DMN and DAN was 58 percent.

Correlation matrix of pairwise RSFC comparing High and Low Performance Groups

A correlation matrix was created to investigate the pairwise correlations between each ROI and the 17 other ROIs (i.e., investigating within-network and cross-network at the individual ROI-level).

Figure 9 depicts the correlation matrix for the entire sample. The top half of the matrix is colour coded to represent the relative strength of correlations for all the pairwise correlations, regardless of statistical significance, while the bottom half is only coloured in cells that have statistically significant values. As expected, and converging with results from the ANOVA, ROIs within each network have stronger within-network RSFC than cross-network RSFC.

Figure 10 shows a side-by-side comparison of the correlation matrices for the High versus Low Performance Group. From this matrix, it appears that the DMN and FPC have slightly higher cross-network RSFC in the Low Performance Group than in the High Performance Group. However, a direct contrast between these two matrices was calculated by conducting a two-samples *t*-test (Figure 11). Only eleven of the 153 pairwise correlations were significant, without correcting for multiple comparisons (displayed in the lower half of the matrix).

RSFC Analyses Using Task-Based Coordinates

A second set of analyses were conducted using task-based coordinates. For these analyses, two key ROIs from each network were investigated. These ROIs were individually localized for each participant based on task-related activation, as previously described.

The DMN ROIs included the right angular gyrus and the left anterior cingulate, the DAN ROIs included the right superior parietal lobule and right precentral gyrus, and finally, the FPC ROIs included the left superior medial frontal gyrus and right superior frontal gyrus (Table 17).

RSFC within and across the RSNs: Task-Based Coordinates

Similar to the literature-based coordinates analyses above, these 2 × 2 × 2 ANOVAs compared group (High versus Low Performance), Network, and Differentiation. Again, the Fisher's z-score, representing the level of RSFC, was the dependent variable. The only significant effect from all of these ANOVAs was a main effect of differentiation found when comparing the DAN to FPC $F(1,110) = 6.491$, $p < 0.05$.

Brain-Behaviour Analysis: Correlating continuous M-capacity scores with pairwise RSFC

Each pairwise correlation from the task-based ROIs was correlated with the FIT and CMT-Clown continuous behavioural measures. Figure 12 displays the statistical significance of the correlations in two 6 × 6 matrices. The first matrix shows the pairwise correlations with the FIT behavioural measure, the second matrix shows the pairwise correlations with the CMT-Clown behavioural measure. The colour coding on the top half of both of these matrices indicates relative strength of correlations for all pairwise RSFC, regardless of statistical significance, while the colouring of the lower half would indicate statistical significance. As seen by the lack of colour, none of the pairwise RSFC were significantly correlated with behavioural measures.

Correlation Matrices Comparing High and Low Groups

A correlation matrix was created to investigate the pairwise RSFC between each ROI and the 5 other ROIs (i.e., within-network and cross-networks).

Figure 13 depicts the correlation matrix for the entire sample. Converging with the insignificant results from the ANOVA, there were no systematic differences in RSFC within- or cross-networks.

Figure 14 shows a side-by-side comparison of the correlation matrix for the High versus Low Performance Group. Two-sample *t*-tests were conducted to directly contrast these matrices however, none of the *t*-statistics were significant ($p < 0.05$; Figure 15). There were no systematic relationships within- or cross- networks that would indicate that there was a difference in RSFC between the High and Low Performance Groups.

Seed-Based Whole-brain RSFC Analysis

A seed-based whole-brain RSFC analysis was conducted for both the High and Low Performance Groups to compare whole-brain voxelwise correlations for each of the six data-driven ROIs. Two-sample *t*-tests were conducted to contrast the High Performance Group with the Low Performance Group. When the *t*-test results were corrected using FDR, there were no significant results. I therefore used a more liberal approach in order to explore the trends. The results of the *t*-tests below are from this more liberal approach, where $p < 0.05$, without any correction for multiple comparisons. Figure 16 displays the location of all ROI seeds used in this analysis.

DMN Seed-Based Whole-brain RSFC Analysis

The right angular gyrus showed RSFC with various regions of the brain for both the High and Low Performance Groups. Figure 17 displays the areas that differed significantly ($p < 0.05$, uncorrected) in RSFC after conducting a *t*-test. As indicated with yellow, the right angular gyrus of participants in the High Performance Group had higher RSFC with other areas of the brain than in the Low Performance Group. However, the right middle frontal gyrus, left superior temporal gyrus, and the left precentral gyrus had lower RSFC with the right angular gyrus in the High Performance Group than the Low Performance Group (Table 17).

The left anterior cingulate also showed RSFC with other brain regions for both the High and Low Performance Groups. The *t*-test revealed that the RSFC between the left anterior cingulate and the right cuneus was the only set of regions that had a difference between the High and the Low Performance Groups (Figure 17, Table 17).

DAN Seed-Based Whole-brain RSFC Analysis

The right superior parietal lobule showed RSFC with various regions of the brain for both the High and Low Performance Groups. Figure 18 displays the areas that differed significantly between the High and Low Performance Groups after conducting a *t*-test. The blue indicates the areas that had higher RSFC with the right superior parietal lobule in the Low Performance Group than in the High Performance Group, whereas the yellow indicates the areas that had higher RSFC with the right superior parietal lobule in the High Performance Group than in the Low Performance Group (Table 17).

The right precentral gyrus also showed RSFC with brain regions for both the High and Low Performance Groups. Figure 18 displays the areas that differed significantly in RSFC between the High and Low Performance Group after conducting a *t*-test. Similar to the right superior parietal lobule, areas throughout the brain that had higher RSFC with the right precentral gyrus in the Low Performance Group than the High Performance Group are indicated with blue. There were a small number of regions (right superior frontal gyrus, left middle temporal gyrus, and left cerebellum) that had higher RSFC in the High Performance Group than the Low Performance Group, indicated with yellow (Table 17).

FPC Seed-Based Whole-brain RSFC Analysis

The RSFC of the left superior medial gyrus in both the High and Low Performance Groups showed RSFC across various areas of the brain. Figure 19 displays the areas that differed significantly in RSFC between the two groups after conducting a *t*-test. As indicated with yellow, there were areas of the brain that had higher RSFC in the High Performance Group than in the Low Performance Group. However, both the right and left angular gyri and the PCC of the DMN, and the left inferior frontal gyrus had higher RSFC in the Low Performance Group than the High Performance Group (Table 17).

The right superior frontal gyrus showed RSFC with various areas of the brain for both the High and Low Performance Groups. Figure 19 displays the areas that differed significantly in RSFC between the two groups after conducting a *t*-test. The blue indicates the areas that had higher RSFC with the right superior frontal gyrus in the Low Performance Group than in the High Performance Group, whereas the yellow indicates the areas that had higher RSFC with the right superior frontal gyrus in the High Performance Group than in the Low Performance Group (Table 17).

Discussion

The aim of this study was to identify RSFC differences in groups that scored high versus low on M-capacity tasks. Pascual-Leone's TCO describes how M-capacity is age-determined, in accordance with Piaget's stage theory of cognitive development. According to this theory all adults that develop successfully should reach the maximum M-capacity of 7 by the time they are 16 years old (Pascual-Leone & Baillargeon, 1994). The TCO does not allow for individual variations in M-capacity within each age group. Our sample consisted of participants that were all between the ages of 20 and 30 years old so, theoretically, all of these participants should have the highest level of M-capacity. However, half of our sample did not achieve their age-appropriate M-capacity; thus, there may be some fundamental difference in these individuals. However, I was unable to reject my null hypotheses and could not conclude that the High and Low Performance Groups differed in any statistically significant way.

Analyses that addressed the fifth hypothesis, however, which states that there would be stronger RSFC between the FPC and DMN in the Low Performance Group than in the High Performance Group, revealed some interesting results.

The uncorrected *t*-test contrast of High and Low Performance Groups from the whole-brain seed-based analyses showed that the left superior medial gyrus of the FPC had higher RSFC with the right and left angular gyri and PCC of the DMN in the Low Performance Group than in the High Performance Group, and that the High Performance Group had higher RSFC between the seeded FPC region and other FPC regions, such as the Pcu and superior frontal gyrus. These brain patterns, although not statistically significant, are exactly what we would expect to see.

Additionally, the two-sample *t*-tests that were conducted to contrast the pairwise RSFC in the High and Low Performance Groups resulted in a slightly greater number of significant negative *t*-statistics (indicating higher RSFC in the Low Performance Group) when comparing cross-network pairwise correlations than when comparing the within-network pairwise correlations. Although this difference between groups is slight, these results are worth considering.

Finally, the brain-behaviour analysis (using literature-determined coordinates) revealed a greater number of significant negative correlations between M-capacity score and cross-network pairwise RSFC than between M-capacity score and within-network pairwise RSFC. This indicates that individuals with lower M-capacity scores (on a continuous scale) had higher cross-network RSFC. Consistent with my hypothesis, I found higher cross-network RSFC between the FPC and DMN correlated with lower performance on M-capacity. Contrary to my hypothesis, however, I also saw that stronger cross-network RSFC between the DMN and DAN was correlated with lower M-capacity performance. I had hypothesized that there would be a stronger anticorrelation between these two networks in the High Performance Group. This unexpected result, along with similar unexpected results (e.g., the main effect of group seen in the network-level ANOVAs using the literature-based coordinates) are difficult to interpret. Based on the strong theory behind my hypotheses, I believe that these results may not hold up to more robust analyses and would suggest future research conduct these analyses with different methods, as detailed later.

As discussed in the introduction of this paper, aging research has shown the importance of the FPC and DMN correlation and memory. The DECHA model provides a theory of aging and describes how RSFC between these networks are crucial to changes in cognitive performance; older adults have higher RSFC between these two networks and perform worse on memory tasks than young adults (Spreng et al., 2018). Other research that analyzed these connections in young adults found similar results. For example, Keller et al., (2015) found a negative relationship between working memory capacity and cross-network RSFC between the FPC and DMN. We see in both aging and lifespan research how an increase in this connection, perhaps specifically due to the DMN not disengaging from the FPC appropriately, results in reduced cognitive performance. This is not exclusive to memory. In a study conducted by Koyama and colleagues (2017), numeracy ability was directly affected by the right MFG, a core component of the FPC. Additionally, they found that RSFC between the rMFG and the DMN negatively correlated with numeracy scores. This indicates that the DMN-FPC relationship plays a role in cognitive performance. Similarly, Franzmeier and colleagues (2017) found correlations between less education and stronger FPC-DMN correlations. The combination of my results and the literature provide compelling reasons to further analyze the differences between performance level on M-capacity tasks and RSFC across the FPC and DMN, however slightly different methods should be implemented, as discussed later.

I had hypothesized that individuals who performed better on the M-capacity tasks would, at rest, have (1) stronger RSFC among regions within the DMN; (2) stronger RSFC among regions within the DAN; and (3) stronger RSFC among regions within the FPC. These hypotheses were not supported; *t*-tests that compared High and Low Performers' within-network RSFC did not yield any significant differences after controlling for multiple comparisons, and the ANOVAs showed no significant interactions involving group. There was a significant main effect of group in the network-level ANOVAs which indicates that the Low Performance Group has slightly higher RSFC than the High Performance Group, however, this trend is seen systematically within and across every network. This is an unusual effect and could be due to some underlying difference between the groups, or due to an unknown difference that occurred during data acquisition.

At the ROI-level, the results from these ANOVAs did not support any of our hypotheses. The only statistically significant interaction was between ROI and differentiation. These interactions were seen when comparing the DMN nodes to the FPC, FPC nodes to the DMN, and DMN nodes to the DAN. As we discovered from the post-hoc analyses, these interaction effects were the result of some ROIs having smaller differences between their within-network RSFC and their cross-network RSFC than other ROIs. Interestingly, it is only the analyses involving the DMN that had this interaction of ROI and differentiation. It is possible that the RSFC of PHC (i.e., ROI 5) in particular was driving these effects. The PHC and hippocampal region have been shown to be functionally segregated from the rest of the DMN (Andrews-Hanna et al., 2010). Research by Spreng and colleagues (2016) identified reduced within-network RSFC of the PHC specifically as a hallmark of reduced memory function in older adults.

The fourth hypothesis, that the High Performance Group would have a stronger anticorrelation between the DMN and DAN at rest, compared to the Low Performance Group, was not supported. There were no significant three-way interactions between group, network, and differentiation in the ANOVA comparing the DMN and DAN. I would have expected to see the High Performance Group having high RSFC within the DMN, weak RSFC within the DAN, and weak cross-network RSFC, whereas this difference would not be as pronounced in the Low Performance Group. Although no significant difference was found when conducting pairwise RSFC correlation matrices, we can see in the brain-behaviour analyses that there is a larger proportion of negative correlations in the sub-matrix comparing DMN and DAN RSFC, and more significant correlations within the DMN whereas there is only one significant correlation within the DAN. These results, although not conclusive, are intriguing and warrant further investigation in future studies.

The results from this study do not provide evidence to conclude that there is a difference in RSFC in High versus Low Performance Groups. The insignificant results could be due to a true lack of difference in RSFC in High versus Low Performers. However, the trends toward statistical significance discussed above, as well as the literature, provide compelling reasons to believe that a true difference may exist. It is possible that there may be some differences between brain activity in individuals who perform well on M-capacity tasks and individuals who do not perform well on the M-capacity tasks, however, for a number of reasons, our study was not able to establish any statistically significant relationships.

Limitations and Future Directions

As discussed above, previous research on RSNs shows that the strength of within- and cross-network RSFC are associated with performance on behavioural tasks, including memory performance. The objective of this study was to extend this previous research to understand how RSFC might be related to individual differences in M-capacity. The rationale behind my hypotheses was primarily based on research on neural correlates of working memory and the neural effects of aging and cognition, which show that differences in the strength of RSFC and anticorrelation within and across these RSNs are associated with declining performance on memory tasks in older adults. Aging research has shown that stronger RSFC within the DMN, DAN, and FPC and stronger RSFC anticorrelation between the DMN and DAN resulted in better memory performance. Aging research has additionally shown that older adults, who perform worse on memory tasks than younger adults, have stronger cross-network correlation between the FPC and the DMN (e.g., Grady et. al., 2016). Therefore, I expected to find similar RSFC trends when analyzing High versus Low Performance participants, however the results were not statistically significant. There are several potential reasons why this may be the case.

First, there was a total of 29 participants included in the analyses in this study. With specific regard to power for the brain-behaviour analysis, the generally accepted sample size is a minimum of 100, and some argue that even 100 is not enough (Dubois & Adolphs, 2017), especially since reliability of the RSFC brain measures are unknown (see de Haas, 2018 for a detailed description of importance of reliability in brain-behaviour analyses). It is possible that more participants would be needed in order to detect statistically significant brain-behaviour correlations.

Second, for the majority of the analyses, the continuous behavioural measure was dichotomized due to the distribution of scores. Compared to using continuous data, dichotomizing the behavioural results can reduce the F-statistic (Mcclellend & Irwin, 2003). Unfortunately, due to the skewed distribution of our behavioural results, I was not able to perform most analyses using the scores as continuous data. Ideally, analyses should be conducted without dichotomizing the scores, and this may be achieved through increasing the variability in the behavioural scores, as discussed below.

Third, the participants recruited all had a similar background, with everyone having at least some university education. The variability in the behavioural results was low, with 86 percent of participants scoring in the top three (out of six) M-capacity levels (Figure 20). It is possible that this analysis was not sensitive enough to detect the subtle differences in M-capacity from such a homogenous pool of participants. Future research should include individuals with a more varied range of M-capacity scores to obtain a sample that can be better analyzed.

Fourth, the task-based ROI coordinates, although determined using the same sample, were defined during task rather than at rest. Despite the ROIs locations likely being more accurate, some brain regions do not associate with the same neural networks during task as they do during rest (Spreng et al., 2013). Without defining key regions from the rest data, the locations are not necessarily accurate. Additionally, only using two task-based ROIs per network reduced the amount of information we can analyze by over-simplifying the RSNs.

Finally, individually localizing regions of each network in individual participants may be extremely beneficial in future studies. Using group defined ROIs can often result in increased error due to individual differences across participants. Research has shown that individual localization increases the sensitivity of fMRI analyses. For example, Stevens and colleagues (2017) studied the Visual Word Form Area (VWFA) and because they individually localized this region, they were able to better understand the specificity of function. Stevens and colleagues (2017) argued that previous with different findings with regard to the function of the VWFA could be due to the differences in the methods employed. Specifically, previous studies used group-level analyses in standard atlas space to localize functional regions. The precise location of the VWFA differs within individuals, thus using *a priori* coordinates from a standard atlas may have resulted in error.

In addition to using individually localized ROIs, it would be beneficial to identify ROIs from a parcelization of each subject's resting-state data as another way of minimizing individual differences. This would provide us with a more accurate measures of RSFC, ensuring that information we extract better represents the activity of RSNs.

Hopefully, using the suggested improvements, the hypotheses of this study can be tested using robust data and more sophisticated methods of analysis. This will allow us to obtain a more in-depth understanding of the relationship between M-capacity performance and RSFC within- and cross-RSNs.

Tables

Table 1: Descriptive statistics of the participants in the High Performance and Low Performance Groups

	High Performance	Low **Performance**	Both Groups
CMT-Clown			
Age	*M =23.3 (SD =3.15)*	*M =22.57 (SD = 2.41)*	*M = 22.9 (SD =2.47)*
Sex	9 males	5 males	14 males, 15 females
M-capacity Range	6	0-5	0-6
n	14	15	29*
FIT			
Age	*M =* ***23.57*** *(SD =**4.2**)*	*M =**22.72*** *(SD = **2.22**)*	*M = 22.9 (SD =2.47)*
Sex	5 males	9 males	14 males
M-capacity Range	8	4-7	0-8
n	9	19	28*

**n* represents participants included in analyses. Participants were excluded due missing or irregular data.

Table 2: ROI coordinates for each of the three RSNs taken from the literature (Yeo et al., 2011).

Network	Brain Region	MNI Coordinates		
		x	y	z
Default Mode Network (DMN)	1. Superior Frontal Gyrus	-27	23	48
	2. Inferior Parietal Lobe	-41	-60	29
	3. Anterior Temporal Lobe	-64	-20	-9
	4. Medial Prefontal Cortex	-7	49	18
	5. Parahippocampal Cortex	-25	-32	-18
	6. Posterior Cingulate Cortex	-7	-52	26
Dorsal Attention Network (DAN)	1. Frontal Eye Fields	-22	-8	54
	2. Inferior Precentral Sulcus	-34	-38	44
	3. Superior Parietal Lobe	-18	-69	51
	4. Anterior Middle Temporal	-51	-64	-2
	5.Superior Occipital Gyrus	-8	-63	57
	6. Dorsolateral Prefrontal Cortex	-49	3	34
Fronto-Parietal Cortex (FPC)	1. Rostrolateral Prefrontal Cortex	-40	50	7
	2. Anterior Inferior Parietal Lobe	-43	-50	46
	3.Middle Temporal Gyrus	-57	-54	-9
	4.Medial Superior Frontal Gyrus	-5	22	47
	5. Dorsal Anterior Cingulate Cortex	-6	4	29
	6. Precuneus	-4	-76	45

Table 3: ROI coordinates for the three RSNs taken from task data (task-based) from a previous study.

		MNI Coordinates		
		x	y	z
DMN	Right Angular Gyrus	-27	60	48
	Left Anterior Cingulate	9	-48	0
DAN	Right Superior Parietal Lobe	-21	78	57
	Right Precentral Gyrus	-45	-6	33
FPC	Left Superior Medial Gyrus	-3	-24	51
	Right Superior Frontal Gyrus	-30	-3	60

Table 4: 2×2×2 ANOVA Comparing DMN to DAN

	df	*SS*	*MS*	*F*	*p*
Group	1	0.230	0.230	6.016	0.0158*
Network	1	0.018	0.018	0.481	0.4893
Differentiation	1	4.309	4.309	112.808	0.000***
Group-Network Interaction	1	0.007	0.007	0.180	0.6719
Group – Differentiation Interaction	1	0.000	0.000	0.008	0.9272
Network – Differentiation Interaction	1	0.018	0.018	0.481	0.4893
Group – Network - Differentiation Interaction	1	0.007	0.007	0.180	0.6719
Residuals	108	4.126	0.038		

Table 5: 2×2×2 ANOVA Comparing DMN to FPC

	df	*SS*	*MS*	*F*	*p*
Group	1	0.275	0.2747	8.790	0.00373**
Network	1	0.063	0.0627	2.005	0.15963
Differentiation	1	1.208	1.2083	38.657	0.000***
Group-Network Interaction	1	0.002	0.0019	0.059	0.80819
Group – Differentiation Interaction	1	0.000	0.0003	0.010	0.92224
Network – Differentiation Interaction	1	0.063	0.0627	2.005	0.15963
Group – Network - Differentiation Interaction	1	0.002	0.0019	0.059	0.80819
Residuals	108	3.376	0.0313		

Table 6: 2×2×2 ANOVA Comparing DAN to FPC

	df	*SS*	*MS*	*F*	*p*
Group	1	0.181	0.18074	5.950	0.0163*
Network	1	0.149	0.14895	4.904	0.0289*
Differentiation	1	0.251	0.25071	8.254	0.0049**
Group-Network Interaction	1	0.002	0.00160	0.053	0.8189
Group – Differentiation Interaction	1	0.002	0.00247	0.081	0.7761
Network – Differentiation Interaction	1	0.149	0.14895	4.904	0.0289*
Group – Network - Differentiation Interaction	1	0.002	0.00160	0.053	0.8189
Residuals	108	3.281	0.03038		

Table 7: Tukey's HSD Post-Hoc Analysis for DAN to FPC Network-Differentiation Interaction Results.

	Diff	lwr	upr	*p*
FPC(Cross-Network) – DAN (Across-Network)	2.220446e-16	-0.11943749	0.11943749	1.0000000
DAN (Within-Network) – DAN (Across-Network) ***Main effect Differentiation***	1.646486e-01	0.04521114	0.28408611	0.0027046*
FPC (Within-Network) – DAN (Across-Network)	2.131161e-02	-0.09812588	0.14074909	0.9663905
DAN (Within-Network) – FPC (Across-Network)	1.646486e-01	0.04521114	0.28408611	0.0027046*
FPC (Within-Network) – FPC (Across-Network) ***Main effect Differentiation***	2.131161e-02	-0.09812588	0.14074909	0.9663905
FPC (Within-Network) – DAN (Within-Network) ***Main effect Network***	-1.433370e-01	-0.26277450	-0.02389953	0.0118267*

Table 8: 6×2×2 ANOVA comparing DAN to FPC

	df	*SS*	*MS*	*F*	*p*
Group	1	0.445	0.4450	11.137	0.000945***
Differentiation	1	2.358	2.3585	59.026	0.000***
ROI	5	0.496	0.0993	2.484	0.031583*
Group – Differentiation Interaction	1	0.024	0.0241	0.604	0.437606
Group – ROI Interaction	5	0.069	0.0137	0.343	0.886558
Differentiation – ROI Interaction	5	0.316	0.0632	1.582	0.164648
Group – Differentiation – ROI Interaction	5	0.011	0.0021	0.053	0.998241
Residuals	324	12.946	0.0400		

Table 9: 6×2×2 ANOVA comparing FPC to DAN

	df	*SS*	*MS*	*F*	*p*
Group	1	0.445	0.4450	11.137	0.000008***
Differentiation	1	2.358	2.3585	59.026	0.3276
ROI	5	0.496	0.0993	2.484	0.000000***
Group – Differentiation Interaction	1	0.024	0.0241	0.604	0.9339
Group – ROI Interaction	5	0.069	0.0137	0.343	0.9406
Differentiation – ROI Interaction	5	0.316	0.0632	1.582	0.0887
Group – Differentiation – ROI Interaction	5	0.011	0.0021	0.053	0.9403
Residuals	324	12.946	0.0400		

Table 10: 6×2×2 ANOVA comparing DMN to FPC

	df	*SS*	*MS*	*F*	*p*
Group	1	0.965	0.965	22.090	0.000000***
Differentiation	1	5.464	5.464	125.062	0.000000***
ROI	5	1.462	0.292	6.691	0.000000***
Group – Differentiation Interaction	1	0.011	0.011	0.250	0.617509
Group – ROI Interaction	5	0.026	0.005	0.119	0.988115
Differentiation – ROI Interaction	5	1.154	0.231	5.282	0.000111***
Group – Differentiation – ROI Interaction	5	0.048	0.010	0.219	0.954051
Residuals	324	14.156	0.044		

Table 11: Tukey's HSD Post-Hoc Analysis for DMN to FPC ROI-Differentiation Interaction Results (significant results only regarding ROI 5- PHC).

	diff	lwer	lwr	P adj
Within-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 1	-0.23705724	-0.41777105	-0.056343429	0.0012450
Cross-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 1	-0.30758195	-0.48829577	-0.126868142	0.0000029
Within-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 2	-0.27851655	-0.45923036	-0.097802740	0.0000419
Cross-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 2	-0.34904126	-0.52975508	-0.168327452	0.0000000
Within-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 3	-0.25267931	-0.43339312	-0.071965498	0.0003685
Cross-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 3	-0.32320402	-0.50391784	-0.142490211	0.0000006
Within-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 4	-0.21522069	-0.39593450	-0.034506878	0.0059782
Cross-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 4	-0.28574540	-0.46645921	-0.105031590	0.0000221
Within-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 6	0.31309310	0.13237929	0.493806916	0.0000017
Cross-Network Connectivity of ROI 5 Compared to Within-Network Connectivity of ROI 6	0.38361782	0.20290400	0.564331628	0.0000000

Table 12: 6×2×2 ANOVA comparing FPC to DMN

	df	*SS*	*MS*	*F*	*p*
Group	1	0.694	0.6945	17.133	0.000004***
Differentiation	1	2.162	2.1617	53.329	0.000000***
ROI	5	1.098	0.2196	5.419	0.000005***
Group – Differentiation Interaction	1	0.002	0.0020	0.049	0.8250
Group – ROI Interaction	5	0.039	0.0079	0.195	0.9644
Differentiation – ROI Interaction	5	0.567	0.1133	2.796	0.0173*
Group – Differentiation – ROI Interaction	5	0.046	0.0092	0.226	0.9511
Residuals	324	13.133	0.0405		

Table 13: Tukey's HSD Post-Hoc Analysis of FPC (to DMN) Network-Differentiation Interaction Results

	diff	lwr	upr	P adj.
Cross Network of ROI 13 – Within Network of ROI 13	-0.246021724	-0.42008737	-0.071956081	0.0002954
Cross Network of ROI 14 – Within Network of ROI 13	-0.272336667	-0.44640231	-0.098271023	0.0000289
Cross Network of ROI 15 – Within Network of ROI 13	-0.196838391	-0.37090403	-0.022772747	0.0122616
Cross Network of ROI 16 – Within Network of ROI 13	-0.190426322	-0.36449197	-0.016360678	0.0186304
Within Network of ROI 16 – Within Network of ROI 13	-0.227067586	-0.40113323	-0.053001943	0.0013748
Cross Network of ROI 17 – Within Network of ROI 13	-0.324742989	-0.49880863	-0.150677345	0.0000002
Within Network of ROI 14 – Cross Network of ROI 13	0.235357586	0.06129194	0.409423230	0.0007121
Within Network of ROI 15 – Cross Network of ROI 13	0.226023103	0.05195746	0.400088747	0.0014911
Within Network of ROI 16 – Cross Network of ROI 13	0.187263793	0.01319815	0.361329437	0.0227547
Cross Network of ROI 14 – Within Network of ROI 14	-0.261672529	-0.43573817	-0.087606885	0.0000760
Cross Network of ROI 15 – Within Network of ROI 14	-0.186174253	-0.36023990	-0.012108609	0.0243536
Cross Network of ROI 16 – Within Network of ROI 14	-0.179762184	-0.35382783	-0.005696540	0.0359381
Within Network of ROI 17 – Within Network of ROI 14	-0.216403448	-0.39046909	-0.042337805	0.0030929
Cross Network of ROI 17 – Within Network of ROI 14	-0.314078851	-0.48814449	-0.140013207	0.0000005
Within Network of ROI 15 – Cross Network of ROI 14	0.252338046	0.07827240	0.426403690	0.0001724
Within Network of ROI 16 – Cross Network of ROI 14	0.213578736	0.03951309	0.387644379	0.0038075
Cross Network of ROI 15 – Within Network of ROI 15	-0.176839770	-0.35090541	-0.002774127	0.0426515
Within Network of ROI 17 – Within Network of ROI 15	-0.207068966	-0.38113461	-0.033003322	0.0060779
Cross Network of ROI 17 – Within Network of ROI 15	-0.304744368	-0.47881001	-0.130678724	0.0000012
Cross Network of ROI 17 – Within Network of ROI 16	-0.265985057	-0.44005070	-0.091919414	0.0000516
Within Network of ROI 18 – Cross Network of ROI 17	0.190563678	0.01649803	0.364629322	0.0184675

Table 14: 6×2×2 ANOVA comparing DMN to DAN

	df	*SS*	*MS*	*F*	*p*
Group	1	0.949	0.949	19.224	0.000001***
Differentiation	1	11.295	11.295	228.829	0.000000***
ROI	5	0.513	0.103	2.077	0.0679
Group – Differentiation Interaction	1	0.013	0.013	0.258	0.6121
Group – ROI Interaction	5	0.035	0.007	0.140	0.9829
Differentiation – ROI Interaction	5	1.748	0.350	7.083	0.000000***
Group – Differentiation – ROI Interaction	5	0.053	0.011	0.216	0.9588
Residuals	324	15.992	0.049		

Table 15: Tukey's HSD Post-Hoc Analysis of DMN (to DAN) Network-Differentiation Interaction Results

	Diff	Lwr	Upr	P adj
Within network of ROI 5 Compared to within ROI 1	-0.237057241	-0.42913584	-0.04497864	0.0034748
Cross-network of ROI 5 Compared to within ROI 1	-0.316833678	-0.50891228	-0.12475508	0.0000071
Within network of ROI 5 Compared to within ROI 2	-0.278516552	-0.47059515	-0.08643795	0.0001715
Cross-network of ROI 5 Compared to within ROI 2	-0.358292989	-0.55037159	-0.16621439	0.0000002
Within network of ROI 5 Compared to within ROI 3	-0.252679310	-0.44475791	-0.06060071	0.0011834
Cross-network of ROI 5 Compared to within ROI 3	-0.332455747	-0.52453435	-0.14037715	0.0000018
Within network of ROI 5 Compared to within ROI 4	-0.215220690	-0.40729929	-0.02314209	0.0138140
Cross-network of ROI 5 Compared to within ROI 4	-0.294997126	-0.48707572	-0.10291853	0.0000457
Within network of ROI 5 Compared to within ROI 6	0.313093103	0.12101451	0.50517170	0.0000099
Cross-network of ROI 5 Compared to within ROI 5	-0.207081034	-0.39915963	-0.01500244	0.0221953
Cross-network of ROI 5 Compared to cross ROI 6	0.392869540	0.20079094	0.58494814	0.0000000

Table 16: 6×2×2 ANOVA comparing DAN to DMN

	df	*SS*	*MS*	*F*	*p*
Group	1	0.403	0.403	8.295	0.00424*
Differentiation	1	14.291	14.291	294.336	0.000000***
ROI	5	0.232	0.046	0.956	0.444482
Group – Differentiation Interaction	1	0.015	0.015	0.311	0.57736
Group – ROI Interaction	5	0.028	0.006	0.116	0.98884
Differentiation – ROI Interaction	5	0.331	0.066	1.365	0.23708
Group – Differentiation – ROI Interaction	5	0.019	0.004	0.078	0.99554
Residuals	324	15.731	0.049		

Table 17: Cluster table from seed-based analyses *t*-tests.

			Critical Mass			Peak Activation			
seed region	connectivity region	Number of Voxels	X	Y	Z	X	Y	Z	*t* Value
R. Angular Gyrus	L. Superior Medial Gyrus	279	-11.3	-52.7	23.1	-1.5	-61.5	1.5	3.48
	L. Superior Frontal Gyrus	174	31.5	-35.6	40	19.5	-46.5	34.5	3.73
	L. Precentral Gyrus	84	40.8	-8.8	15.9	43.5	-4.5	19.5	-3.04
	L. Cerebellum (VII) (within 2 mm)	82	26.4	66.3	-49.7	19.5	67.5	-55.5	3.54
	R. Precuneus	79	-2.1	80.9	57.7	-1.5	76.5	64.5	3.23
	L. Middle Temporal Gyrus	72	62.5	53.8	-19.6	64.5	52.5	-10.5	2.96
	L. Hippocampus	61	10.7	31.3	3.1	22.5	31.5	7.5	3.48
	L. Inferoir Temporal Gyrus	60	63	19.5	-26.9	64.5	28.5	-28.5	3.92
	L. Superior Temoral Gyrus	57	46.2	35.4	10.3	43.5	34.5	10.5	-2.9
	R. Middle Orbital Gyrus	53	-18.6	-67.3	-15.4	-19.5	-67.5	-13.5	3.79
	R. Anngular Gyrus	49	-42	72.1	39.8	-43.5	70.5	40.5	2.98
	L. Inferior Parietal Lobe	47	51.6	48.1	56.4	52.5	43.5	58.5	3.11
	R. Middle Frontal Gyrus	42	-50.2	-7.3	55.8	-43.5	-1.5	61.5	-3.475
L. Anterior Cingulate	R. Cuneus	41	-16.1	98.9	7.4	-7.5	97.5	13.5	3.24
R. Superior Parietal Lobe	Right Inferior Frontal Gyrus	259	-44.1	-7.1	0	-49.5	-13.5	1.5	-3.93
	L. Postcentral Gyrus	221	28.3	27.2	48.1	43.5	16.5	34.5	-4.58
	L. Inferior Frontal Gyrus	190	46.5	-4.6	3.5	49.5	-7.5	7.5	-4.4
	R. Superior Frontal Gyrus	179	-33.1	-24	40	-28.5	-25.5	52.5	4.07
	L. Calcarine Gyrus	138	11.5	81.5	9.3	7.5	91.5	7.5	-3.86
	R. Superior Orbital Gyrus	116	-16.5	-63.5	2	-19.5	-67.5	-1.5	3.69
	R. Precuneus (within 4 mm)	96	-23.1	52.5	21.2	-34.5	49.5	13.5	3.65
	L. Middle Frontal Gyrus	46	26.2	-34.4	47	28.5	-28.5	49.5	3.65
	L. Inferoir Frontal Gyrus	44	38.2	-41.4	-3.5	43.5	-40.5	-4.5	3.11
	R. Precuneus (within 5 mm)	41	-5.4	82	57.8	-4.5	79.5	64.5	3.13
R. Precentral Gyrus	R. Inferior Frontal Gyrus	196	-48.8	-0.3	13.7	-46.5	-4.5	22.5	-3.37
	R. Superior Frontal Gyrus	84	-22	-57.1	11.2	-25.5	-58.5	4.5	3.85
	L. Middle Temporal Gyrus	75	54.8	76.5	13	58.5	73.5	19.5	3.54
	L. Inferior Frontal Gyrus	71	36.5	-5.3	17.8	37.5	-1.5	25.5	-3.26
	L. Postcentral Gyrus	54	50.6	24	26.6	52.5	19.5	28.5	-3.16
	R. SMA	51	-14.3	1.7	44.8	-4.5	1.5	49.5	-3.07
	L. Middle Cingulate Cortex	45	18.1	32.2	47.6	19.5	34.5	37.5	-4.18
	L. Hippocampus (within 3mm)	41	37.1	3.6	-24	34.5	1.5	-25.5	-3.29
	L. Cerebellum (VII) (within 2 mm)	40	29.7	61.8	-48.6	28.5	67.5	-46.5	4.58
L. Superior Medial Gyrus	L. Superior Frontal Gyrus	96	23.6	1.2	70.3	19.5	-4.5	70.5	3.21
	R. Superior Frontal Gyrus	96	-16.2	3.5	74.7	-19.5	7.5	76.5	4.47
	R. Insula	96	-44.7	-21.8	-8.5	-43.5	-22.5	-7.5	3.84
	L. Precuneus	85	3.4	57.7	35	-1.5	64.5	34.5	2.64
	R. Angular Gyrus	61	-53.6	54.1	32.1	-49.5	55.5	34.5	-3.29
	R. Inferior Frontal Gyrus	48	-57.5	-14.2	28	-58.5	-10.5	25.5	3.19
	L. Inferior Frontal Gyrus	43	30.6	-21.7	30	31.5	-10.5	31.5	-2.74
R. Superior Frontal Gyrus	R. Superior Parietal Lobe	86	-40.5	69.3	46.6	-37.5	76.5	55.5	2.83
	L. Inferoir Parietal Lobe	69	54.3	51.5	45.7	55.5	49.5	43.5	3.22
	R. Superior Medial Gyrus	54	-14.6	-35.9	59.7	-10.5	-46.5	52.5	-3.33
	R. Thalamus (within 3 mm)	52	-22.1	22.6	19.2	-22.5	25.5	19.5	3.54
	L. Hippocampus	49	20.6	37.4	9.5	16.5	37.5	7.5	3.66
	R. Middle Temporal Gyrus	48	-71.3	33.1	-0.9	-70.5	37.5	4.5	-3.22
	L. Parahippocampal Gyrus (within 1mm)	46	18.1	9.5	-20.7	13.5	19.5	-19.5	3.64
	L. Superior Temporal Gyrus	43	47.9	37.8	17.8	40.5	37.5	22.5	-2.8
	L. Fusiform Gyrus	42	38.3	23.8	-30.7	37.5	25.5	-25.5	3.08
	R. Cuneus	42	-5	76.2	30.1	-7.5	76.5	34.5	-3.32

Near Neighbor Level, Bi-sided, Min number of voxels = 40, Coordinate order = RAI, $p < 0.05$ (uncorrected

Figures

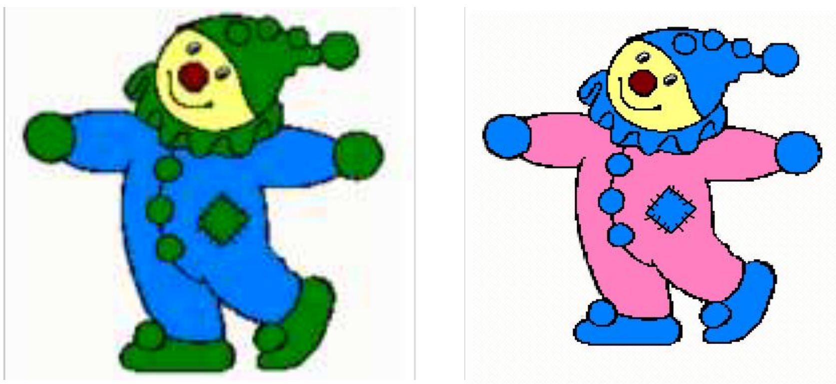

Figure 1: Example of clown stimulus. Participants are told to ignore the colours on the clown's face, as well as blue and green. In the control clown condition (L), participants view this stimulus where, aside from the clown's face, the only colours presented are blue and green. In this task clown condition (R), participants must remember only one colour, pink.

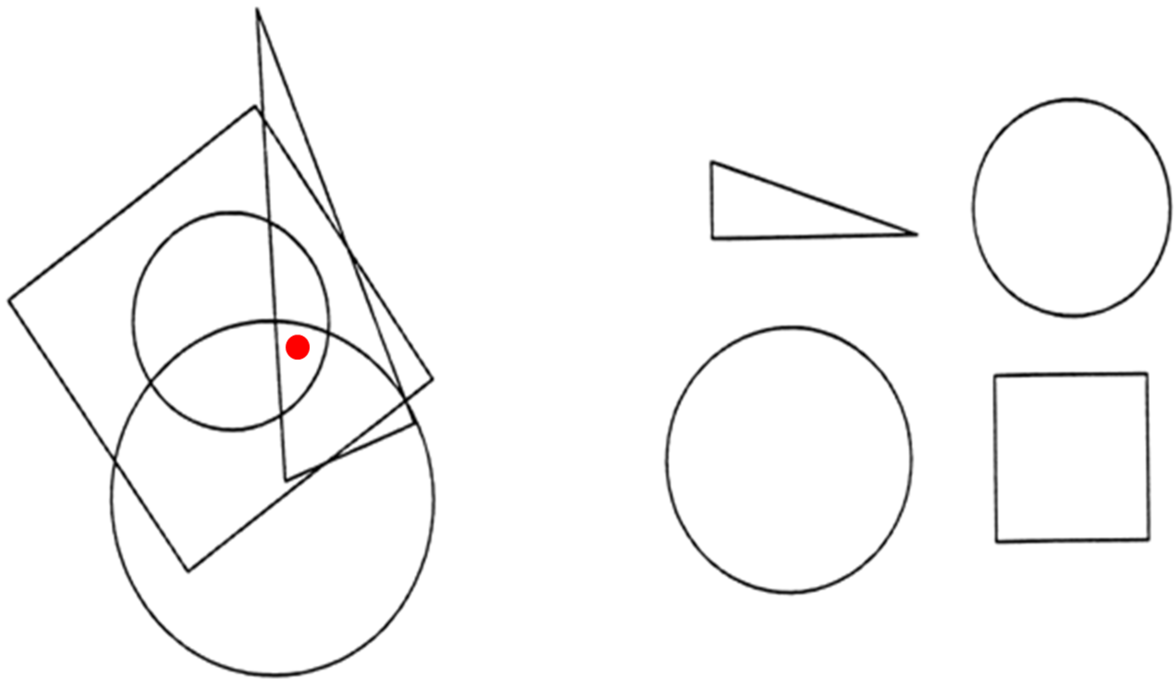

Figure 2: Example of figure insertion task. Participants are provided with images of shapes that do not overlap (R). They are then provided with an image where shapes overlap (L). They are instructed to indicate the location where these shapes intersect, irrespective of the shape’s size and orientation, indicated by the red circle (L).

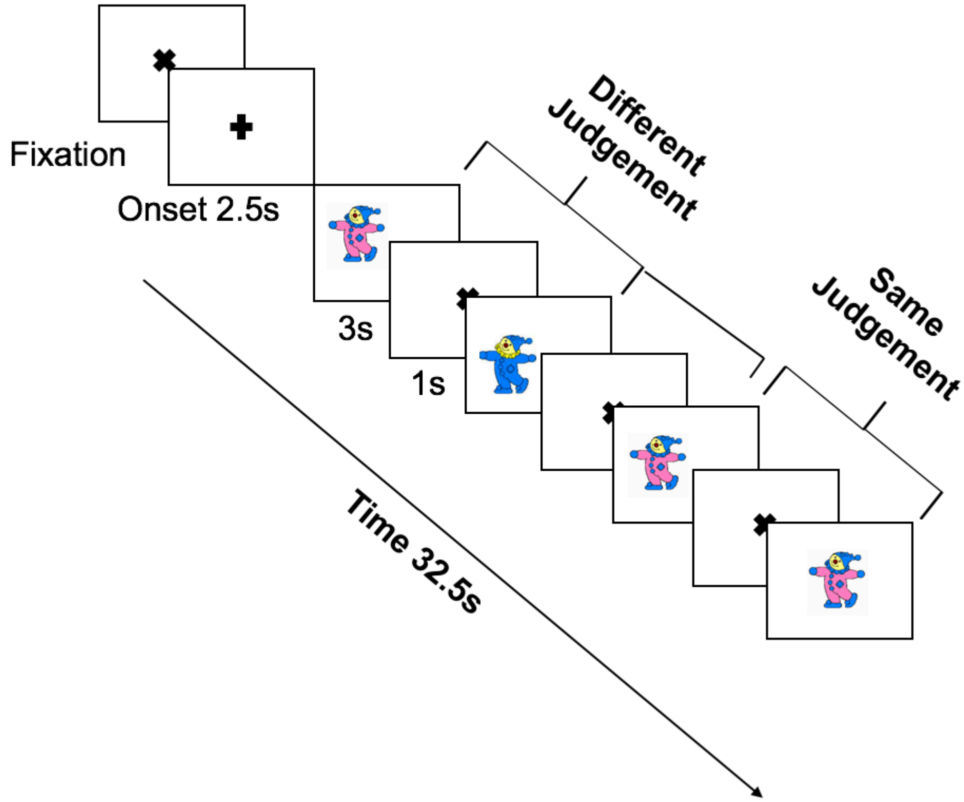

Figure 3: Task Structure. Each block presented a series of eight images belonging to one difficulty level. Each stimulus was presented for 3 s followed by an ISI of 1 s. Each block lasted 32 s, which included all eight images and a 1.5 s offset cue at the end of the block signifying that a period of fixation was to follow. Task blocks were interleaved by 10 s periods of fixation and a 2.5 s block-onset cue.

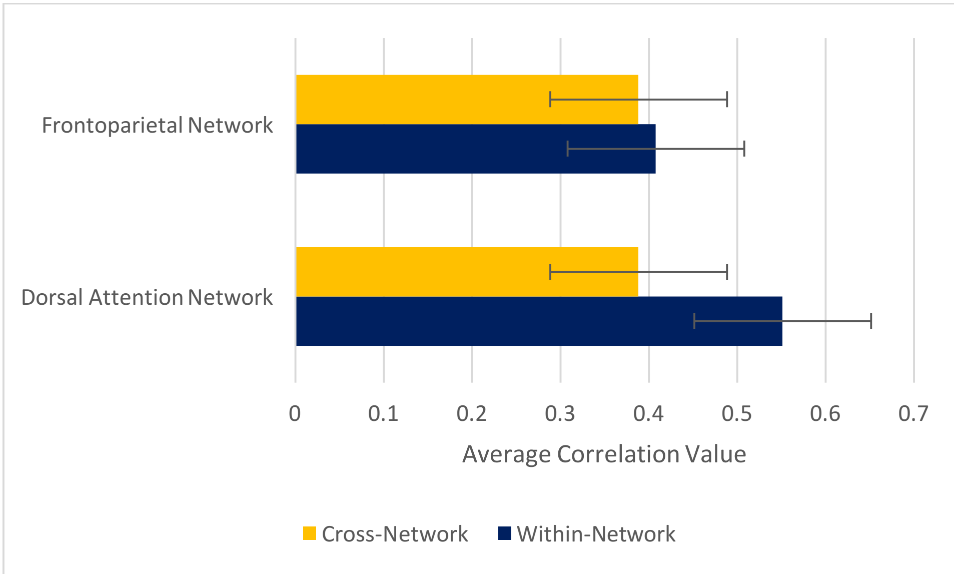

Figure 4: DAN-FPC. Graphical representation of the interaction between network and differentiation in the literature-determined coordinates of DAN and FPC Tukey's post-hoc analysis.

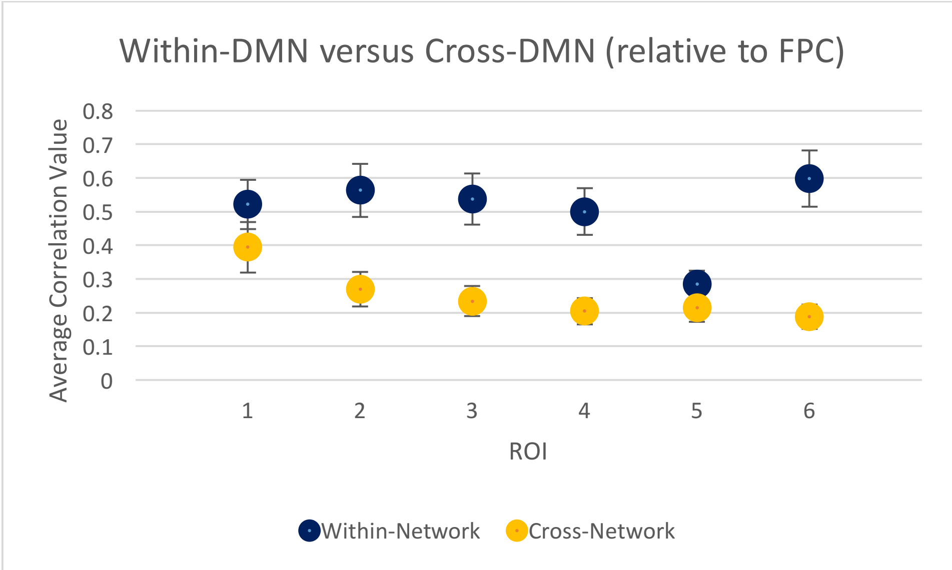

Figure 5: DMN-FPC. Graphical representation of the interaction between ROI and differentiation in the DMN (to FPC) Tukey's post-hoc analysis. (Literature-based coordinates).

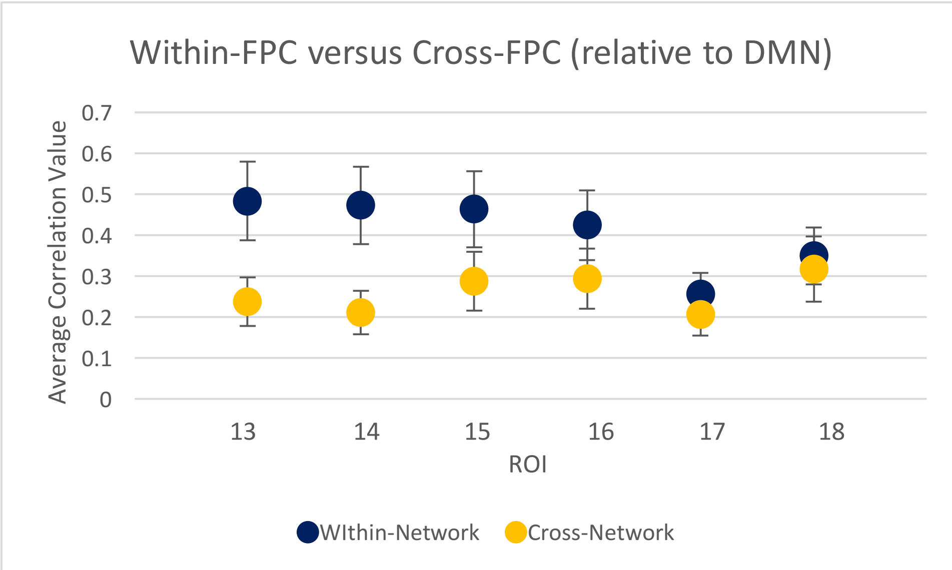

Figure 6: FPC-DMN. Graphical representation of the interaction between ROI and differentiation in the FPC (to DMN) Tukey's post-hoc analysis. (Literature-based coordinates).

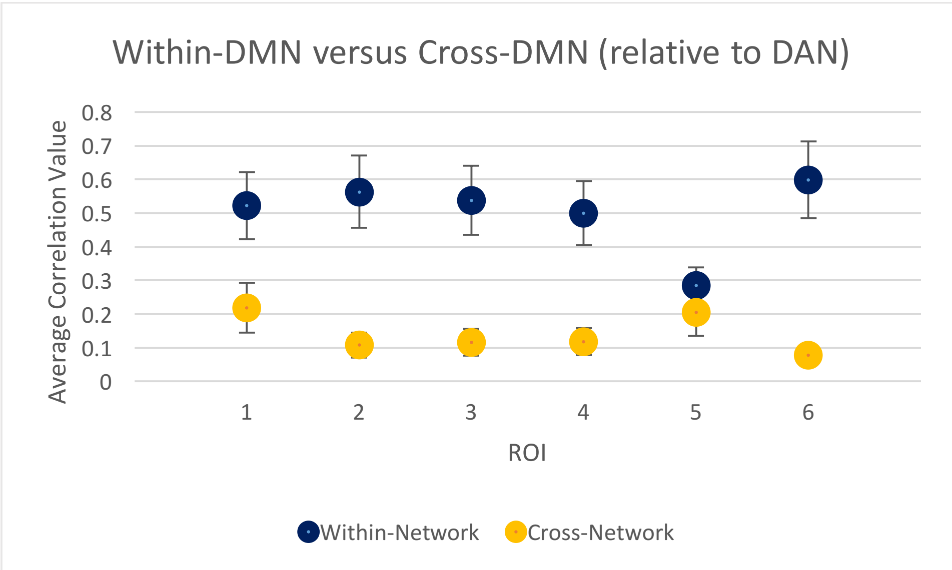

Figure 7: DMN-DAN. Graphical representation of the interaction between ROI and differentiation in the DMN (to DAN) Tukey's post-hoc analysis. (Literature-based coordinates).

	DMN 1	2	3	4	5	6	DAN 7	8	9	10	11	12	FPCN 13	14	15	16	17	18
DMN 1	------	-0.175	-0.489	-0.353	-0.083	-0.283	-0.193	-0.033	-0.437	-0.346	-0.023	-0.376	-0.247	-0.175	-0.238	-0.429	-0.400	-0.088
2	-0.175	------	-0.234	-0.381	-0.306	-0.424	-0.330	-0.247	-0.441	-0.452	-0.195	-0.463	-0.013	-0.039	-0.157	-0.366	-0.264	-0.176
3	-0.489	-0.234	------	-0.237	-0.405	-0.312	-0.481	-0.334	-0.606	-0.560	-0.375	-0.590	-0.362	-0.323	-0.592	-0.498	-0.478	-0.474
4	-0.353	-0.381	-0.237	------	-0.412	-0.361	-0.330	-0.201	-0.331	-0.485	-0.261	-0.510	-0.223	-0.267	-0.332	-0.389	-0.364	-0.340
5	-0.083	-0.306	-0.405	-0.412	------	-0.356	-0.304	-0.431	-0.449	-0.449	-0.268	-0.504	-0.351	-0.214	-0.410	-0.297	-0.475	-0.287
6	-0.283	-0.424	-0.312	-0.361	-0.356	------	-0.374	-0.343	-0.460	-0.442	-0.364	-0.605	-0.304	-0.215	-0.372	-0.516	-0.389	-0.155
DAN 7	-0.193	-0.330	-0.481	-0.330	-0.304	-0.374	------	-0.052	-0.182	-0.375	-0.247	0.011	-0.357	-0.110	-0.235	-0.311	-0.260	-0.325
8	-0.033	-0.247	-0.334	-0.201	-0.431	-0.343	-0.052	------	-0.173	-0.125	-0.100	-0.090	-0.238	-0.073	-0.093	-0.141	-0.377	-0.281
9	-0.437	-0.441	-0.606	-0.331	-0.449	-0.460	-0.182	-0.173	------	-0.184	-0.155	-0.305	-0.539	-0.113	-0.468	-0.477	-0.477	-0.351
10	-0.346	-0.452	-0.560	-0.485	-0.449	-0.442	-0.375	-0.125	-0.184	------	-0.165	-0.271	-0.478	-0.019	-0.257	-0.412	-0.431	-0.411
11	-0.023	-0.195	-0.375	-0.261	-0.268	-0.364	-0.247	-0.100	-0.155	-0.165	------	0.014	-0.461	-0.048	-0.102	-0.235	-0.293	-0.369
12	-0.376	-0.463	-0.590	-0.510	-0.504	-0.605	0.011	-0.090	-0.305	-0.271	0.014	------	-0.221	0.002	-0.068	-0.175	-0.402	-0.415
FPCN 13	-0.247	-0.013	-0.362	-0.223	-0.351	-0.304	-0.357	-0.238	-0.539	-0.478	-0.461	-0.221	------	-0.254	-0.356	-0.141	-0.431	-0.417
14	-0.175	-0.039	-0.323	-0.267	-0.214	-0.215	-0.110	-0.073	-0.113	-0.019	-0.048	0.002	-0.254	------	-0.081	0.015	-0.238	-0.206
15	-0.238	-0.157	-0.592	-0.332	-0.410	-0.372	-0.235	-0.093	-0.468	-0.257	-0.102	-0.068	-0.356	-0.081	------	-0.073	-0.374	-0.275
16	-0.429	-0.366	-0.498	-0.389	-0.297	-0.516	-0.311	-0.141	-0.477	-0.412	-0.235	-0.175	-0.141	0.015	-0.073	------	-0.371	-0.307
17	-0.400	-0.264	-0.478	-0.364	-0.475	-0.389	-0.260	-0.377	-0.477	-0.431	-0.293	-0.402	-0.431	-0.238	-0.374	-0.371	------	-0.425
18	-0.088	-0.176	-0.474	-0.340	-0.287	-0.155	-0.325	-0.281	-0.351	-0.411	-0.369	-0.415	-0.417	-0.206	-0.275	-0.307	-0.425	------

Figure 8: **Brain-Behaviour Correlation Analysis with Literature-Based Coordinates.** Correlation of all participants' M-capacity score (on a continuous scale) with ROI pairwise correlations, e.g., (1, 2) represents the correlation from all participants' behavioural measure with all participants' ROI 1,2 pairwise correlation, and in this case, they are not significantly correlated, $p < 0.05$, uncorrected

FZ	DMN1	DMN2	DMN3	DMN4	DMN5	DMN6	DAN7	DAN8	DAN9	DAN10	DAN11	DAN12	FPN13	FPN14	FPN15	FPN16	FPN17	FPN18
DMN1		0.60518571	0.39455714	0.37596429	0.32932857	0.57174286	0.22132857	0.18092143	0.16813571	0.10947857	0.30632857	0.18657857	0.35511429	0.35354286	0.42025	0.45165	0.15779286	0.35002857
DMN2	0.60518571		0.60825714	0.4073	0.21642857	0.61917857	0.06182857	0.08319286	0.07177857	0.02590714	0.11205	0.07485	0.27197857	0.27922857	0.28289286	0.27175714	0.14647857	0.26410714
DMN3	0.39455714	0.60825714		0.61606429	0.20443571	0.55781429	0.07493571	0.08265	0.04637857	-0.0181071	0.06550714	0.01229286	0.21616429	0.12077143	0.10465714	0.22535714	0.10528571	0.19086429
DMN4	0.37596429	0.4073	0.61606429		0.21121429	0.59401429	0.15605714	0.10221429	0.10174286	0.05572143	0.09364286	0.03622857	0.18233571	0.07908571	0.07986429	0.2529	0.15187857	0.21607857
DMN5	0.32932857	0.21642857	0.20443571	0.21121429		0.30108571	0.14910714	0.09835714	0.16047143	0.16132143	0.17863571	0.13638571	0.11822857	0.12728571	0.21195714	0.16610714	0.12849286	0.21725
DMN6	0.57174286	0.61917857	0.55781429	0.59401429	0.30108571		0.03272143	0.02108571	0.03594286	-0.0305	0.04374286	-0.031	0.08675714	0.05886429	0.09372143	0.11881429	0.1006	0.34429286
DAN7	0.22132857	0.06182857	0.07493571	0.15605714	0.14910714	0.03272143		0.51685714	0.56205	0.43555	0.50910714	0.48211429	0.30073571	0.30882143	0.35762857	0.22278571	0.26756429	0.31239286
DAN8	0.18092143	0.08319286	0.08265	0.10221429	0.09835714	0.02108571	0.51685714		0.46962857	0.46415714	0.50299286	0.43015714	0.35226429	0.41847857	0.37592143	0.2429	0.21195714	0.28651429
DAN9	0.16813571	0.07177857	0.04637857	0.10174286	0.16047143	0.03594286	0.56205	0.46962857		0.7453	0.73062143	0.43547857	0.30192143	0.37524286	0.38381429	0.20275714	0.18679286	0.48661429
DAN10	0.10947857	0.02590714	-0.0181071	0.05572143	0.16132143	-0.0305	0.43555	0.46415714	0.7453		0.60742143	0.52195	0.26835	0.42765	0.55022143	0.18840714	0.20808571	0.35562857
DAN11	0.30632857	0.11205	0.06550714	0.09364286	0.17863571	0.04374286	0.50910714	0.50299286	0.73062143	0.60742143		0.43327143	0.35887143	0.47867857	0.48917857	0.22381429	0.20283571	0.57223571
DAN12	0.18657857	0.07485	0.01229286	0.03622857	0.13638571	-0.031	0.48211429	0.43015714	0.43547857	0.52195	0.43327143		0.42339286	0.48655714	0.60857143	0.43565714	0.29178571	0.24578571
FPN13	0.35511429	0.27197857	0.21616429	0.18233571	0.11822857	0.08675714	0.30073571	0.35226429	0.30192143	0.26835	0.35887143	0.42339286		0.56207857	0.43482857	0.61847857	0.19785	0.35766429
FPN14	0.35354286	0.27922857	0.12077143	0.07908571	0.12728571	0.05886429	0.30882143	0.41847857	0.37524286	0.42765	0.47867857	0.48655714	0.56207857		0.59287143	0.47291429	0.17149286	0.34752143
FPN15	0.42025	0.28289286	0.10465714	0.07986429	0.21195714	0.09372143	0.35762857	0.37592143	0.38381429	0.55022143	0.48917857	0.60857143	0.43482857	0.59287143		0.46712143	0.24732143	0.34996429
FPN16	0.45165	0.27175714	0.22535714	0.2529	0.16610714	0.11881429	0.22278571	0.2429	0.20275714	0.18840714	0.22381429	0.43565714	0.61847857	0.47291429	0.46712143		0.21833571	0.24022857
FPN17	0.15779286	0.14647857	0.10528571	0.15187857	0.12849286	0.1006	0.26756429	0.21195714	0.18679286	0.20808571	0.20283571	0.29178571	0.19785	0.17149286	0.24732143	0.21833571		0.18731429
FPN18	0.35002857	0.26410714	0.19086429	0.21607857	0.21725	0.34429286	0.31239286	0.28651429	0.48661429	0.35562857	0.57223571	0.24578571	0.35766429	0.34752143	0.34996429	0.24022857	0.18731429	

Figure 9: **Pairwise Correlation Matrix Between Each ROI.** The shade of red represents the strength of the correlation of each literature-based ROI with all the other 17 ROIs. Data in this matrix are for an average of the entire sample

Figure 10: **Side-By-Side Comparison of ROI Pairwise Correlations.** The shade of red represents the strength of the correlation of each literature-based ROI with all the other 17 ROIs. Data in this matrix are divided into High Performance Group (L) and Low Performance Group (R).

	DMN 1	2	3	4	5	6	DAN 7	8	9	10	11	12	FPCN 13	14	15	16	17	18
DMN 1	X	-1.328697	-1.865895	-1.037003	-0.135244	-1.38466	-0.356389	-0.091623	-1.133966	-0.584077	0.0610718	-0.679178	-0.873843	-0.377861	-2.035343	-0.546677	-0.486286	-0.196111
2	-1.328697	X	-0.82627	-1.759272	-0.830663	-2.098712	-0.836742	-0.524194	-1.086613	-0.631665	0.2197156	-0.86492	0.2941827	0.0077349	-0.726346	-0.54356	0.4966171	-0.678528
3	-1.865895	-0.82627	X	-0.710685	-0.90105	-1.030223	-1.490863	-1.07853	-1.800267	-1.362121	-0.596855	-1.809681	-0.554181	-1.289496	-2.452649	-0.950349	-0.617551	-2.005427
4	-1.037003	-1.759272	-0.710685	X	-0.857329	-0.717513	-0.515935	-0.240501	-0.269264	-0.59846	-0.071675	-1.235291	-0.128492	-1.033305	-1.572635	-0.539177	-0.094114	-1.363244
5	-0.135244	-0.830663	-0.90105	-0.857329	X	-1.295639	-1.203953	-2.614007	-1.718772	-1.125087	-0.909689	-2.294713	-1.219125	-1.459463	-2.224505	-0.944507	-2.301318	-1.183184
6	-1.38466	-2.098712	-1.030223	-0.717513	-1.295639	X	-1.635373	-1.543337	-1.149225	-0.630073	-0.842558	-1.470085	-0.747952	-1.178704	-1.840199	-1.111998	-0.432635	-0.230872
DAN 7	-0.356389	-0.836742	-1.490863	-0.515935	-1.203953	-1.635373	X	0.6239523	0.1307834	-1.059808	-0.19568	0.5955978	-0.563721	-0.307877	0.5817977	-0.780804	-1.394167	-0.79416
8	-0.091623	-0.524194	-1.07853	-0.240501	-2.614007	-1.543337	0.6239523	X	-1.041454	-1.155391	0.2512843	-0.322801	-0.242489	-0.453885	-0.082173	-0.54615	-2.357062	-0.154896
9	-1.133966	-1.086613	-1.800267	-0.269264	-1.718772	-1.149225	0.1307834	-1.041454	X	0.1811329	-0.470539	-1.265189	-1.583214	-1.055945	-1.251737	-1.582084	-2.195604	-0.655886
10	-0.584077	-0.631665	-1.362121	-0.59846	-1.125087	-0.630073	-1.059808	-1.155391	0.1811329	X	-0.14352	-2.053788	-1.907017	-0.63549	-0.692883	-2.427043	-2.719658	-0.141901
11	0.0610718	0.2197156	-0.596855	-0.071675	-0.909689	-0.842558	-0.19568	0.2512843	-0.470539	-0.14352	X	0.8134155	-1.787392	-0.810539	0.1104771	-0.91952	-1.749664	-0.065937
12	-0.679178	-0.86492	-1.809681	-1.235291	-2.294713	-1.470085	0.5955978	-0.322801	-1.265189	-2.053788	0.8134155	X	-0.468194	-0.313752	0.6588324	-1.004051	-1.435709	-0.486243
FPCN 13	-0.873843	0.2941827	-0.554181	-0.128492	-1.219125	-0.747952	-0.563721	-0.242489	-1.583214	-1.907017	-1.787392	-0.468194	X	-0.819831	-1.286457	0.3495641	-1.343699	-1.365454
14	-0.377861	0.0077349	-1.289496	-1.033305	-1.459463	-1.178704	-0.307877	-0.453885	-1.055945	-0.63549	-0.810539	-0.313752	-0.819831	X	-0.79423	-0.327784	-1.628374	-1.163712
15	-2.035343	-0.726346	-2.452649	-1.572635	-2.224505	-1.840199	0.5817977	-0.082173	-1.251737	-0.692883	0.1104771	0.6588324	-1.286457	-0.79423	X	-0.812036	-1.026332	-0.258401
16	-0.546677	-0.54356	-0.950349	-0.539177	-0.944507	-1.111998	-0.780804	-0.54615	-1.582084	-2.427043	-0.91952	-1.004051	0.3495641	-0.327784	-0.812036	X	-0.840941	-0.701684
17	-0.486286	0.4966171	-0.617551	-0.094114	-2.301318	-0.432635	-1.394167	-2.357062	-2.195604	-2.719658	-1.749664	-1.435709	-1.343699	-1.628374	-1.026332	-0.840941	X	-1.235256
18	-0.196111	-0.678528	-2.005427	-1.363244	-1.183184	-0.230872	-0.79416	-0.154896	-0.655886	-0.141901	-0.065937	-0.486243	-1.365454	-1.163712	-0.258401	-0.701684	-1.235256	X

Figure 11: **Contrast Matrix of ROI Pairwise Correlations.** The shade of blue represents the strength of the difference in correlation of each of the literature-based ROIs. Data was contrasted by performing a two-samples t-test, subtracting the Low Performance Group's pairwise correlations from the High Performance Group's pairwise correlations. The lower half of the matrix highlights significant effects, $p < 0.05$, uncorrected.

	DMN 1	DMN 2	DAN 1	DAN 2	FPCN 1	FPCN 2
DMN 1	--	0.01519662	0.09214337	0.08804706	0.20490837	0.05277322
DMN 2	0.01519662	--	0.03202106	-0.0387569	-0.0139139	-0.0126098
DAN 1	0.09214337	0.03202106	--	0.33324754	0.05236374	0.0323973
DAN 2	0.08804706	-0.0387569	0.33324754	--	0.02971028	0.20283714
FPCN 1	0.20490837	-0.0139139	0.02971028	0.02971028	--	0.24783276
FPCN 2	0.05277322	-0.0126098	0.20283714	0.20283714	0.24783276	--

Correlations with FIT Score

	DMN 1	DMN 2	DAN 1	DAN 2	FPCN 1	FPCN 2
DMN 1	--	-0.186555	0.24373355	-0.2810517	-0.0054758	-0.1088743
DMN 2	-0.186555	--	-0.3070276	-0.2727572	-0.350866	-0.0481062
DAN 1	0.24373355	-0.3070276	--	0.20633704	0.09117937	0.27679648
DAN 2	-0.2810517	-0.2727572	0.20633704	--	-0.0560146	-0.2599086
FPCN 1	-0.0054758	-0.350866	0.09117937	-0.0560146	--	0.09256607
FPCN 2	-0.1088743	-0.0481062	0.27679648	-0.2599086	0.09256607	--

Correlations with CMT-Clown Score

Figure 12: **Brain-Behaviour Analysis**. Pairwise correlation scores correlated with behavioural measures of FIT score and CMT-Clown score. The colouring on the top half of the matrices indicate the relative strength of correlation, the lack of colouring on the lower half indicate no statistically significant results, $p < 0.05$, uncorrected.

	DMN 1	DMN 2	DAN 3	DAN 4	FPCN 5	FPCN 6
DMN 1	1	0.0699933	0.0779442	0.0324022	0.1270313	0.2160522
DMN 2	0.0699933	1	0.0180075	0.0810559	0.0937673	0.2176165
DAN 3	0.0779442	0.0180075	1	0.0644635	0.0328359	0.0294179
DAN 4	0.0324022	0.0810559	0.0644635	1	0.0918654	0.055812
FPCN 5	0.1270313	0.0937673	0.0328359	0.0918654	1	0.2188912
FPCN 6	0.2160522	0.2176165	0.0294179	0.055812	0.2188912	1

***Figure 13*: Task-based Pairwise Correlation Matrix.** Pairwise correlations of each ROI with the other five ROIs for the entire sample. The colouring on the top half of the matrix represents the relative correlations, the lack of coloured cells on the bottom half of the matrices represent no significance.

	DMN 1	DMN 2	DAN 3	DAN 4	FPCN 5	FPCN 6
DMN 1	1	0.0801112	0.0768574	0.0268222	0.1311287	0.1955617
DMN 2	0.0801112	1	0.0057261	0.0808543	0.0635086	0.232279
DAN 3	0.0768574	0.0057261	1	0.0472548	0.0392991	0.0244351
DAN 4	0.0268222	0.0808543	0.0472548	1	0.1052577	0.0752971
FPCN 5	0.1311287	0.0635086	0.0392991	0.1052577	1	0.2050688
FPCN 6	0.1955617	0.232279	0.0244351	0.0752971	0.2050688	1

	DMN 1	DMN 2	DAN 3	DAN 4	FPCN 5	FPCN 6
DMN 1	1	0.062104	0.0701834	0.0263387	0.1133391	0.2337876
DMN 2	0.062104	1	0.0253641	0.0822272	0.1135305	0.199029
DAN 3	0.0701834	0.0253641	1	0.0724961	0.022919	0.0284228
DAN 4	0.0263387	0.0822272	0.0724961	1	0.0756279	0.0227631
FPCN 5	0.1133391	0.1135305	0.022919	0.0756279	1	0.2304835
FPCN 6	0.2337876	0.199029	0.0284228	0.0227631	0.2304835	1

***Figure 14:* Side-By-Side Task-Based Pairwise Correlation Matrix.** Data in these matrices were divided into High Performance Group (top) and Low Performance Group (bottom), in order to compare the pairwise correlations of each ROI with the other five ROIs. The colouring on the top half of the matrices represents the relative correlations, the lack of coloured cells on the bottom half of the matrices represent no significance.

	DMN 1	DMN 2	DAN 3	DAN 4	FPCN 5	FPCN 6
DMN 1	--	0.1435504	0.043058	0.003169	0.1061202	-0.280475
DMN 2	0.1435504	--	-0.175575	-0.009802	-0.341828	0.200778
DAN 3	0.043058	-0.175575	--	-0.1719	0.1299241	-0.033122
DAN 4	0.003169	-0.009802	-0.1719	--	0.2098743	0.3008891
FPCN 5	0.1061202	-0.341828	0.1299241	0.2098743	--	-0.174414
FPCN 6	-0.280475	0.200778	-0.033122	0.3008891	-0.174414	--

Figure 15: **Contrast Matrix T-statistics of Task-based ROIs Pairwise Correlation.** A t-test was conducted comparing the High Performance Group's and Low Performance Group's pairwise correlations. The colouring on the top half of the matrix represents relative values of the t-statistics, whereas the lack of colouring on the bottom half of the matrix indicates that no t-statistic was significant at $p < 0.05$.

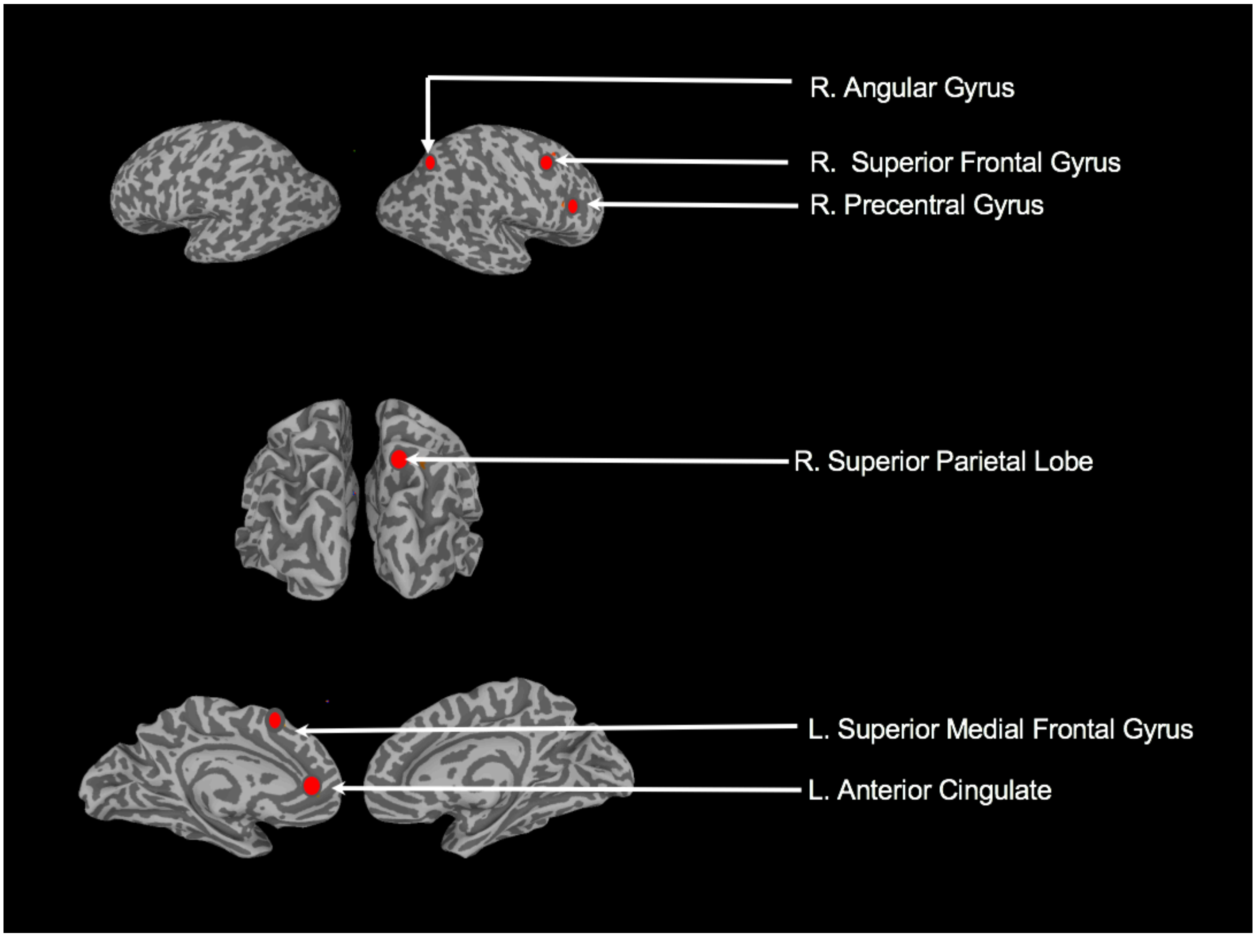

Figure 16: ***Location of all Six Task-Based ROIs.*** 6mm spheres were centered around each task-defined coordinate to create each ROI. The average time series was extracted from these spheres.

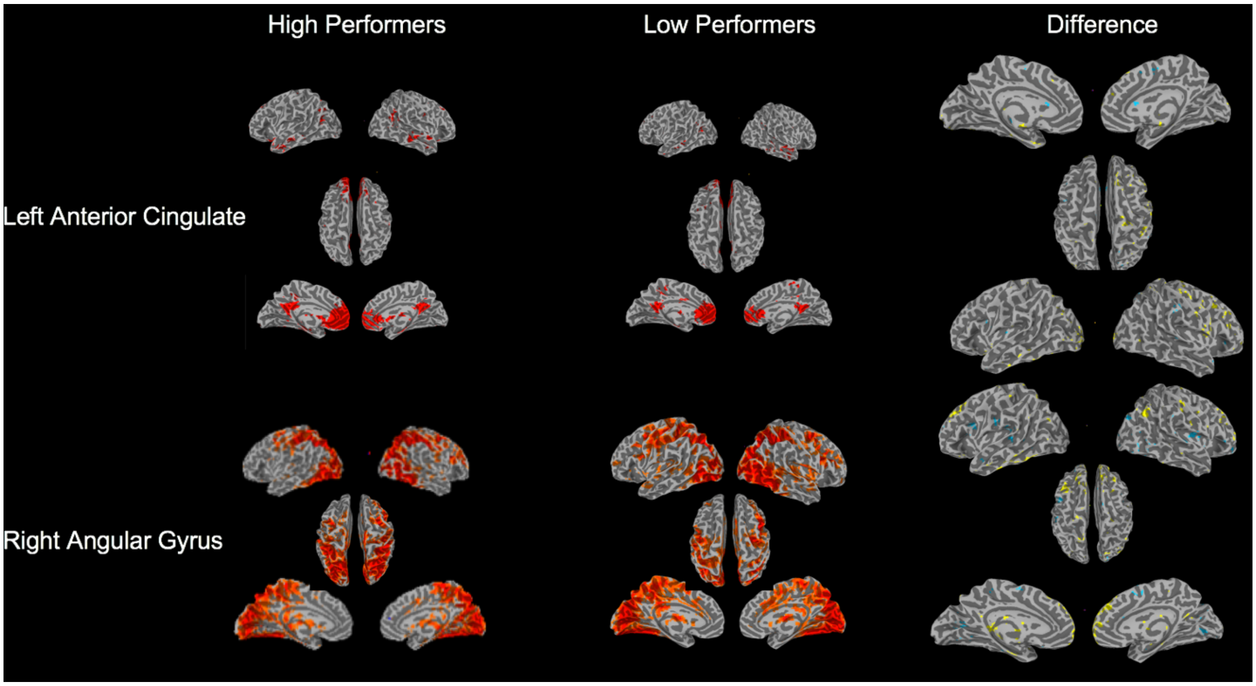

***Figure 17*: Default Mode Network Whole-brain RSFC Analysis.** Whole-brain voxelwise correlations with the Left Anterior Cingulate and Right Angular Gyrus, comparing correlations in High versus Low Performance Groups with a *t*-test, $p < 0.05$, uncorrected.

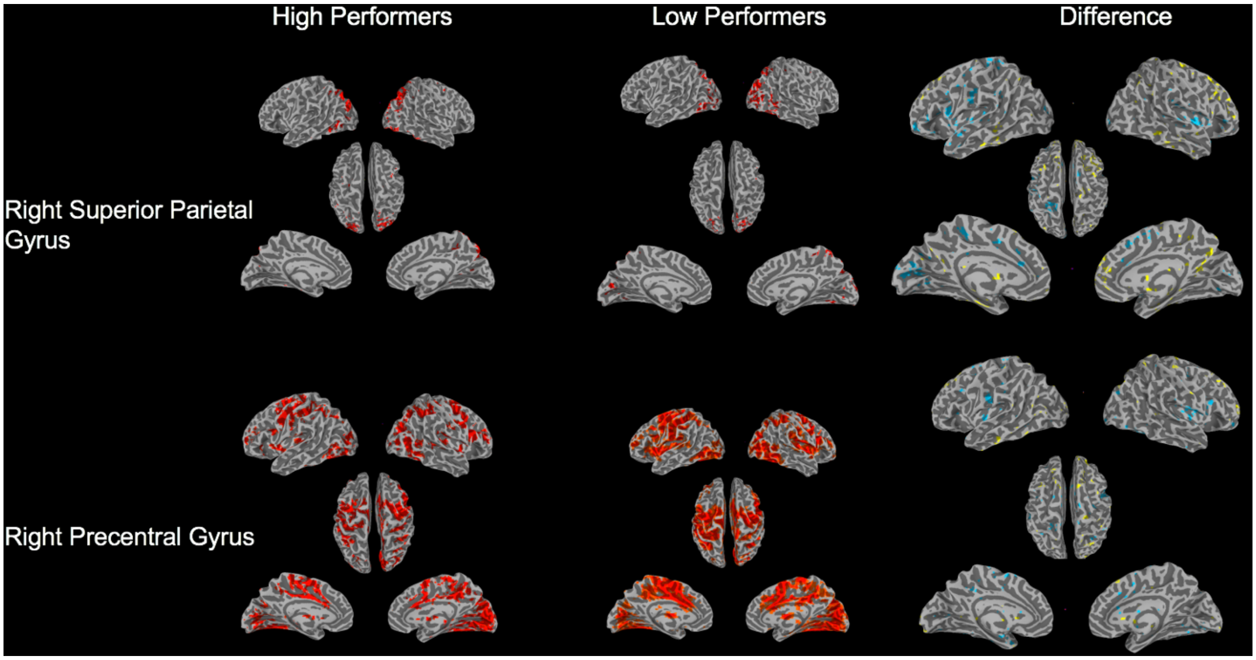

Figure 18: **Dorsal Attention Network Whole-brain RSFC Analysis.** Whole-brain voxelwise correlations with the Right Superior Parietal Lobule and Right Precentral Gyrus, comparing correlations in High versus Low Performance Groups with a *t*-test, $p < 0.05$, uncorrected.

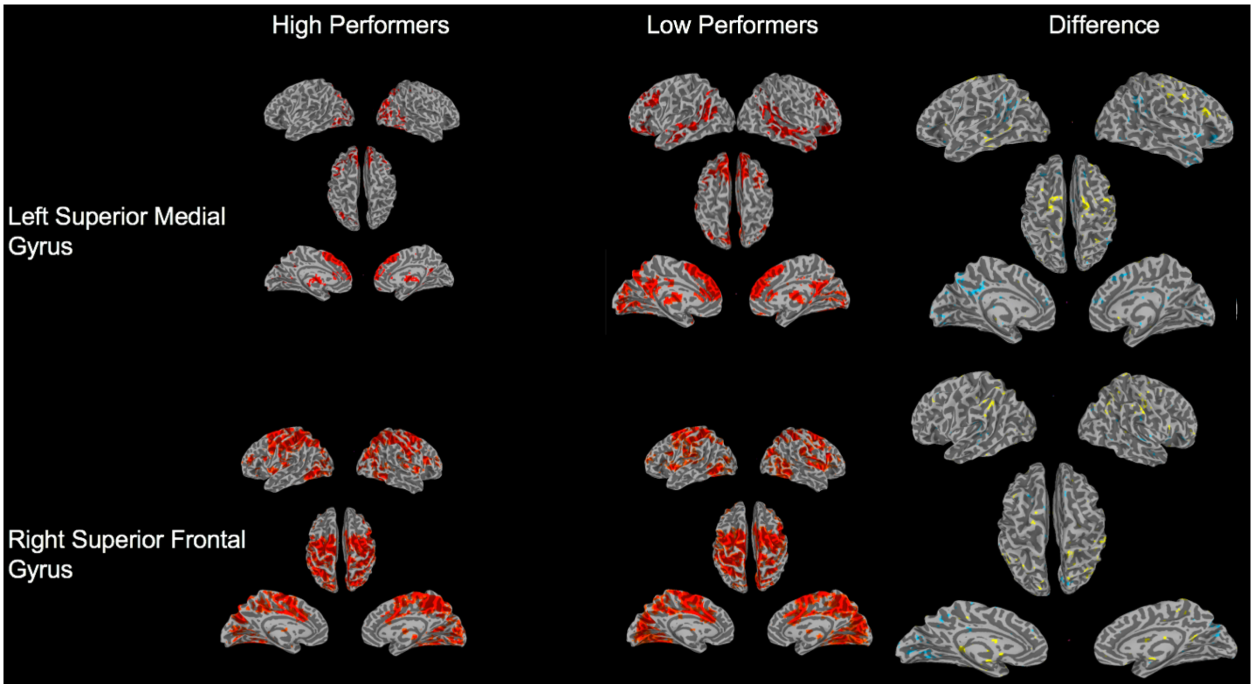

Figure 19**: Frontoparietal Control Network Whole-brain RSFC Analysis.** Whole-brain voxelwise correlations with the and Left Superior Medial Gyrus and, Right Superior Frontal Gyrus comparing correlations in High versus Low Performance Groups with a *t*-test, $p < 0.05$, uncorrected.

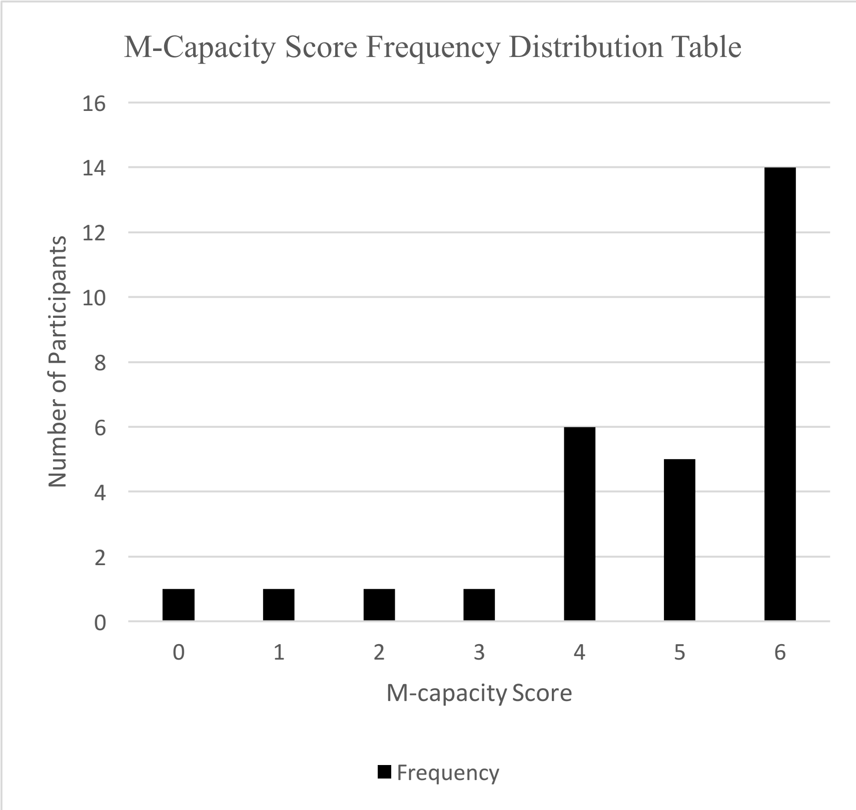

Figure 20*:* Frequency distribution of all participants on CMT-Clown task

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