PNAS

Supporting Information for

Attention Control Ability is Associated with Frontoparietal Control Network Interactions

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Supporting Information Text

Attention Control Tasks

The three tasks used to measure the individual differences in attention control were the Antisaccade, Stroop with an adaptive response deadline, and the Sustained Attention to Cue Task (SACT).

Antisaccade Task (1, 2)

Participants were tasked with identifying either a "Q" or an "O" that appeared briefly on the opposite side of the screen as a visual cue. After a central fixation cross appeared for 1000 ms or 2000 ms, participants heard a brief tone (300 ms) that alerted them to the onset of an asterisk (*), which flashed at a 12.3° visual angle to the left or right of the central fixation for 100 ms. Afterward, the letter “Q” or “O” was presented on the opposite side at 12.3° visual angle of the central fixation for 100 ms, immediately followed by a visual mask (##). Participants had to indicate if they observed the letter as a "Q" or an "O." Participants completed 16 slow practice trials, with letter duration set to 750 ms, followed by 72 test trials. The task was scored based on accuracy as the proportion of correct responses. See **Fig. S1.** for a trial diagram.

Stroop Task with Adaptive Response Deadline (6, 7)

In this task, the words "RED," "GREEN," and "BLUE" were sequentially presented in red, green, or blue font colors. The words were either congruent with the color (e.g., the word “RED” in red font color) or incongruent with the color (e.g., the word “RED” in blue font color). Participants were instructed to identify the font color by pressing 1, 2, or 3 on the number pad, corresponding to green, blue, and red, respectively. To facilitate response mapping, the keys had colored paper with matching colors taped onto them. There was a 2:1 ratio of congruent to incongruent trials with 96 and 288 trials overall. The task was administered over 4 blocks of 72 trials each with an optional rest break between blocks. Practice trials were administered in each block, with 24 response mapping practice trials, 18 standard Stroop trials without response deadlines, and 18 non-adaptive response deadline practice trials.

An adaptive procedure was employed to determine the participant's response deadline threshold, aiming for approximately 75% accuracy. This deadline adjustment was based solely on trial level accuracy on incongruent trials. On each incongruent trial, if an incorrect response was given or the reaction time exceeded the response deadline, the response deadline was extended (allowing more time to respond) for the subsequent trial. Conversely, if a correct response was made and the reaction time fell below the response deadline, the deadline was reduced (allowing less time to respond) for the next trial. The response deadline started at 1.5 seconds. A 3:1 up-to-down ratio was used for the step sizes such that the step size (change in response deadline) for incorrect/too slow of trials was three times larger than the step size for correct/deadline met trials. The step size started at 240:80 ms, decreased to 120:40 ms after 17 incongruent trials, decreased to 60:20 ms after 33 incongruent trials, decreased to 30:10 ms after 49 incongruent trials, decreased to 15:5 ms after 65 incongruent trials, and finally settled at 9:3 ms after 81 incongruent trials. Feedback was given in the form of an auditory tone and the words “TOO SLOW! GO FASTER!” presented in red font when the response deadline was not met. This feedback remained onscreen for 1,000 ms. This task was scored as the mean threshold value from the last four deadline reversals. See **Fig. S2.** for a trial diagram.

Sustained Attention to Cue Task (6, 8)

In this task, participants needed to sustain their attention at a fixed, cued location for a variable amount of time. Each trial began with a 1,000 ms fixation interval. Following the fixation, a 750 ms interval displayed the words "Get Ready!" at a to-be-cued location, accompanied by an alerting tone. This interval was designed to prepare the participant for the upcoming trial. Subsequently, a large circular cue was presented, which gradually shrank to the point of a to-be-attended location. The circle cue on the screen lasted about 500 milliseconds before it was removed from the display. The display then remained blank over a variable wait interval, which lasted between 0 seconds and 2 to 12 seconds, in 500 ms steps (e.g., 2, 2.5, 3, 3.5… seconds). After the wait

interval, an array of letters (B, P, and R) appeared at the cued location, with a target letter displayed in a dark gray at its center. The non-target letters were presented in a silver font and were randomly arranged around the target letter within a 96 × 96-pixel square, with a minimum separation of 24 pixels to prevent overlap. The target array was visible for 250 ms, after which the target letter was masked for 300 ms. After the mask, a response screen with B, P, and R response options appeared, and participants used a mouse to identify the target letter. After a response, there was a blank buffer display presented for 500 ms.
The task consisted of 6 practice trials with feedback. The task had 3 blocks of 22 trials for 66 trials. No feedback was given on the real trials. Each wait interval occurred once per block. There was a self-timed break given after the first and second block of trials. This task was scored as the proportion of correct responses. See **Fig.S3.** for a trial diagram.

Working Memory Capacity Tasks
The three tasks used to measure the individual differences in working memory capacity were the advanced complex span tasks. The "advanced tasks" were used because their larger memory set sizes show better discrimination in high-ability samples (9). The tasks were the Advanced Operation Span, Advanced Symmetry Span, and Advanced Rotation Span tasks.

Advanced Operation Span.
On each trial, participants first solved a mental arithmetic problem (e.g., (3×4) - 6 = 5) by indicating whether the statement was true or false. They were then presented with a single arrow with a to-be-remembered letter. This alternation continued until a variable set-size of letters was presented (set sizes ranged from 3 to 9 letters) participants tried to recall the letters in their correct serial position. There are 14 trials (2 blocks of 7 trials), and each set- size occurs twice (once in each block). The dependent variable is the edit distance score, which, for this task, has a maximum value of 84.

Advanced Symmetry Span
On each trial, participants judged whether a 16×16 grid of black and white squares was symmetrical about the vertical midline. After each symmetry judgement, they were presented with a 4×4 grid with one cell highlighted. The location of the red square was the to-be-remembered spatial location. Participants completed a variable number of alternations (2-7) until a recall screen appeared. Participants then attempted to recall the locations of the red square in their correct serial order. There was a total of 12 trials (2 blocks of 6 trials), set-sizes ranged from 2-7, and each set-size occurred twice (once in each block). The dependent variable is the edit distance score, which, for this task, has a maximum value of 54.

Advanced Rotation Span
On each trial, participants solved mental rotation problem in which they judged whether a rotated letter faced the correct direction or it was mirror-reversed. Each mental rotation problem was followed by a single arrow with a specific direction (8 possible directions; the four cardinal and four ordinal directions) and specific size (small or large). Both the direction and size of the arrow were the to-be-remembered features. This alternation continued until a variable set-size of arrows was presented, when participants tried to recall the set in their correct serial position. There are 12 trials (2 blocks of 6 trials), set-sizes ranged from 2-7, and each set- size occurs twice (once in each block). Once again, the dependent variable is the edit distance score, which, for this task, has a maximum value of 54 (10). See **Fig. S4.** for a trial diagram.

Note: In each task, subjects respond true/false or yes/no to a processing (distractor) task prior to the presentation of each to-be-remembered stimulus. After a variable amount of presentations (depending on the set-size for that trial), a recall screen appears asking the subject to recall the to-be-remember stimulus in order of presentation.

Fluid Intelligence Tasks

The three tasks used to measure the individual differences in fluid intelligence were the three reasoning tasks of Raven's Advanced Progressive Matrices (RAPM), Number Series, and Letter Sets

Raven's Advanced Progressive Matrices (RAPM)– Odd problems (11)
In this task participants were presented with a matrix of figures that follow a logical pattern across rows and columns. For each problem in this task, a 3 × 3 matrix of 8 abstract figures was presented with the bottom-right element missing. Participants had to identify set of rules relating the 8 figures and select one of eight response options that completed the pattern. Participants were given 10 minutes to solve 18 problems (the odd items from the full test). The dependent variable was the total number of correct solutions in the time allotted.

Number Series (12)
Participants were shown a set of numbers (e.g., 1, 1, 2, 3, 5, 8) on a computer screen. Each number in the sequence was determined by some rule. Participants had to identify the rule and select the next number that should occur next in the sequence from five possible alternatives. In the example above, each number is determined by summing the two that came before it, so the next number in the series should be 13. Participants were given 5 minutes to complete 15 problems. The dependent variable was the total number of correct solutions in the time allotted.

Letter Sets (13)
Participants were shown 5 groups of 4-letter sequences, e.g., NOPQ, DEFL, ABCD, HIJK, and UVWX. The goal was to identify the rule that united four of these groups and indicate which group of letters broke the rul. In the example given above, all letter sets followed consecutive alphabetical order, except for DEFL. Participants were given 10 minutes to solve 30 problems. The dependent variable was the total number of correct solutions in the allotted time.

Session 3 N-back Tasks
Participants were asked to perform 1 run of letter 1-back, 1 run of letter 3-back task and a resting scan while functional scans are acquired. These functional scans were counterbalanced. For both n-back tasks, a sequence of letters were presented one at a time on the screen. Subjects were asked to make a response of "match" with the index finger if the letter on the current trial matched what was presented n-trials before or "no match" with the middle finger if the letter did not match n-trials before. The letters were presented for 500ms, and the participants had 2000ms to respond before the next letter is presented.This results in a total trial duration of 2500ms. There were four blocks of each n-back condition, with a 15 second rest block in between each task block.

Behavioral Data Processing
On any given task, missing data were present due to data cleaning and other factors such as a participant not having enough time to complete a task on a given session, and the task program crashing during administration. Data cleaning consisted of 1) removing problematic participants and 2) removing outliers. For the attention control, working memory capacity, and fluid intelligence tasks, problematic participants were detected as having an overall accuracy equal to or less than chance performance and their scores for that task were set to missing. For the complex-span tasks, overall accuracy was assessed based on the processing task (e.g., symmetry judgments for the symmetry span task). Based on this criterion, 3 participants on the Antisaccade and 1 from the SACT were identified as problematic and were removed. For all cognitive tasks, a multi-pass outlier method was used on the task scores. On each pass, z-scores were computed, then univariate outliers were identified as having scores ±3.5 standard deviations or greater from the mean score on that pass, and outlier scores were replaced with missing data. This process for each task was repeated until no further outliers were detected. Based on this procedure, 5 participants on the Operation Span, and 5 on the SACT, and 3 on the StroopDL task were identified and removed.

Figures

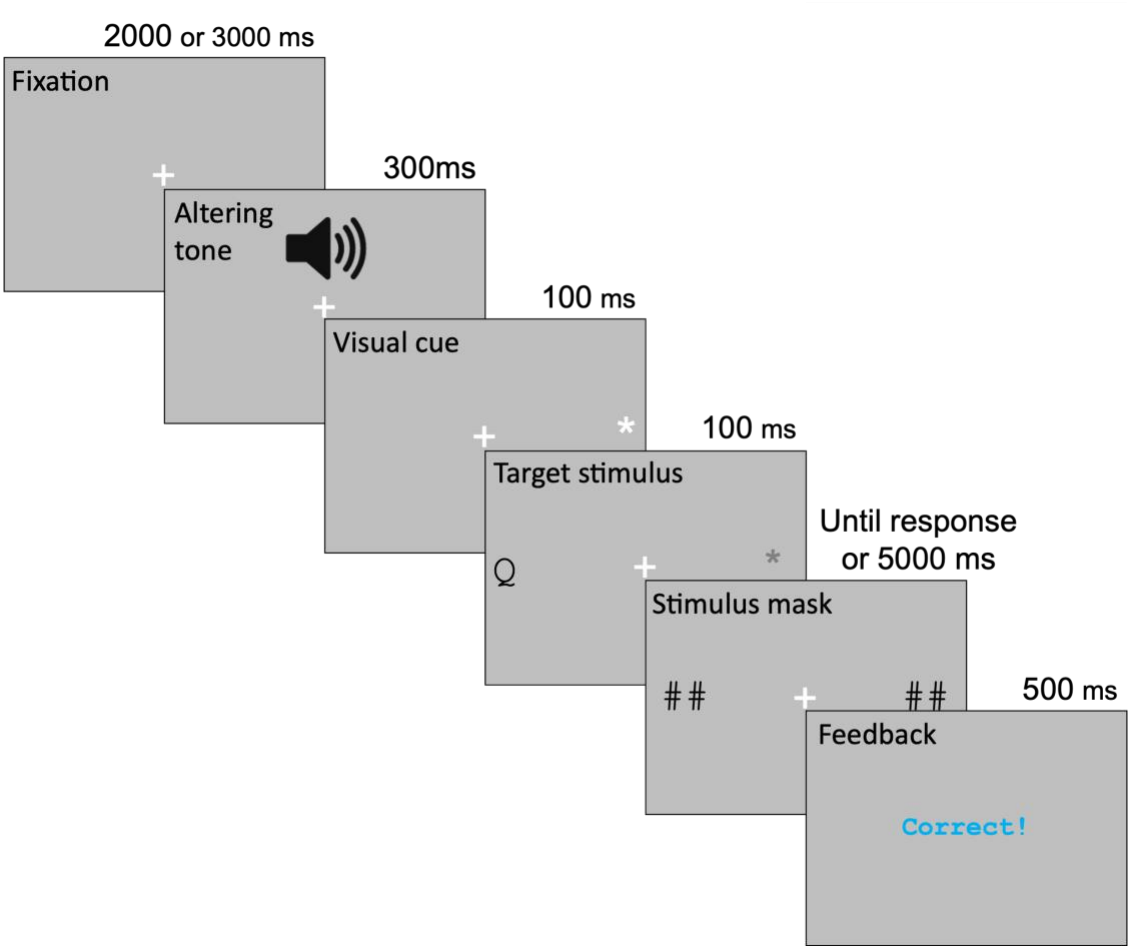

Fig. S1. Diagram of the Antisaccade Task.

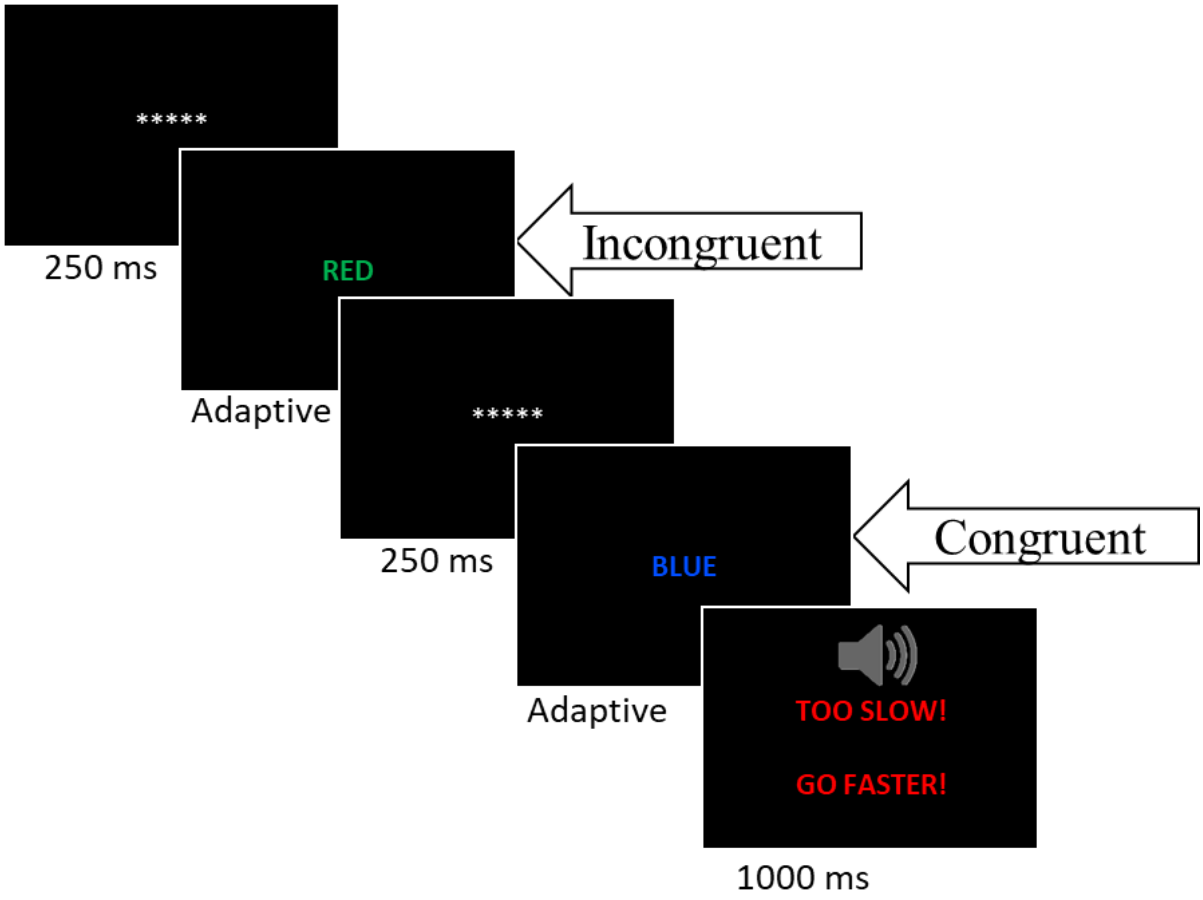

Fig. S2. Diagram of the Adaptive Deadline Color Stroop Task.

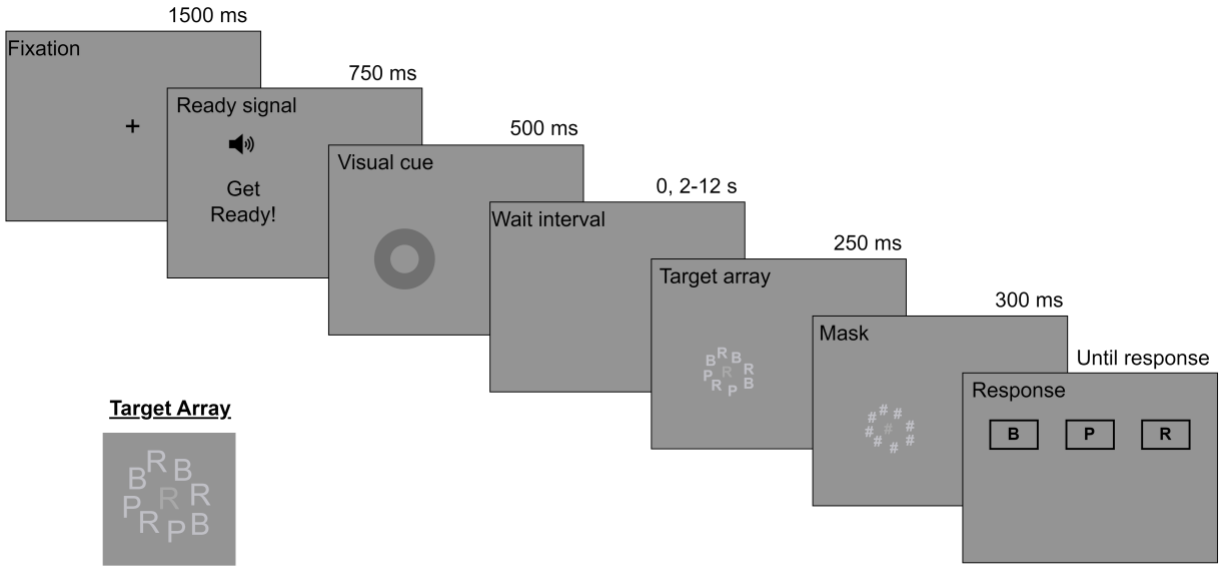

Fig. S3. Diagram of the Sustained Attention to Cue Task.

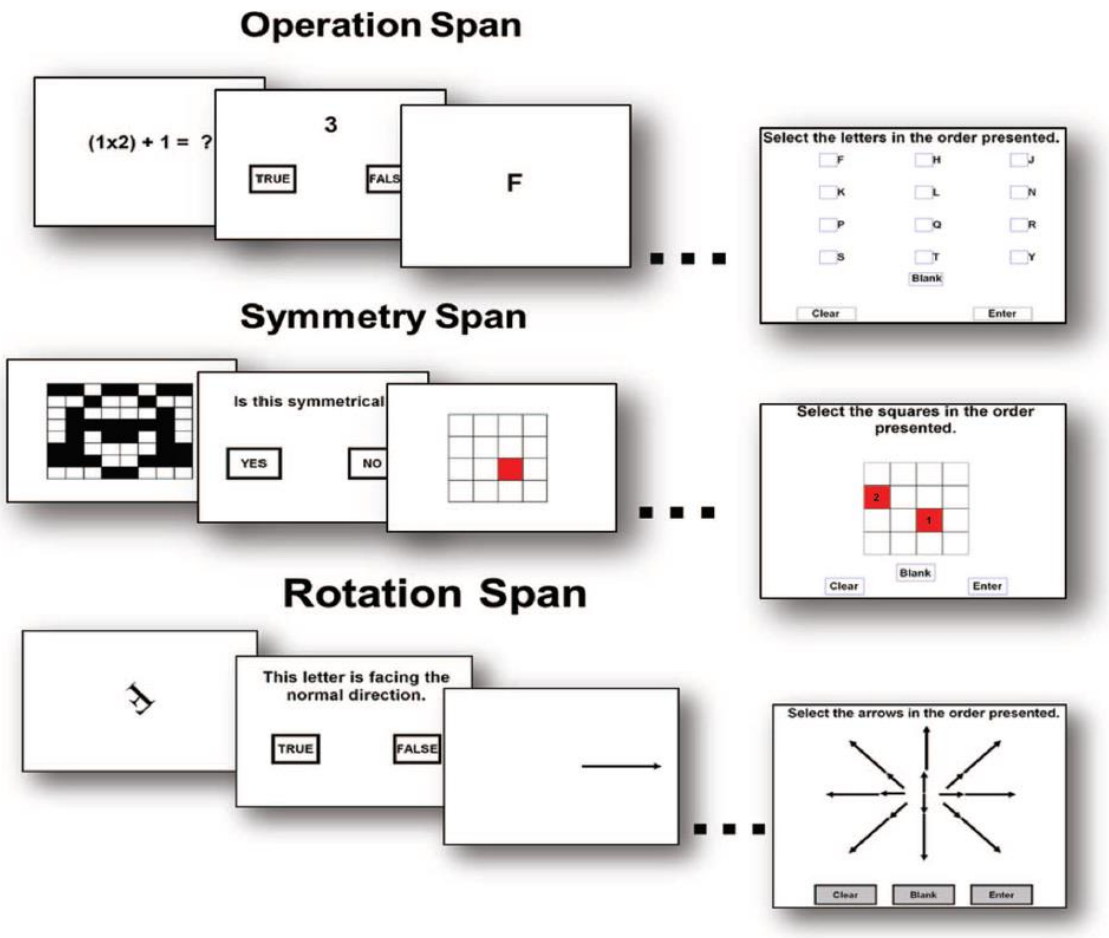

Fig. S4. Diagrams of the Three Complex Span Working Memory Capacity Tasks.

Tables

Table S1. Task Order Across Sessions one and two of the Study. This study was part of a larger data collection effort. As such only, so only tasks relevant to the current set of analyses are described.

Session 1	Session 2
1. Advanced Operation Span	1. Advanced Symmetry Span
2. Letter Sets	2. Raven's Advanced Progressive Matrices (RAPM)
3. Stroop Task with Adaptive Response Deadline	3. Antisaccade Task
4. Advanced Rotation Span	4. *Unreported Task*
5. *Unreported Task*	5. Number Series
6. *Unreported Task*	6. Sustained Attention to Cue Task
7. *Unreported Task*	7. *Unreported Task*
8. *Unreported Task*	8. *Unreported Task*
9. *Unreported Task*	9. *Unreported Task*
10. *Unreported Task*	

Table S2. Confirmatory factor analysis. *AC* attention control, *Gf* fluid intelligence, *WMC* working memory capacity, *SACT* Sustained Attention to Cue Task, *StroopDL* Stroop task with an adaptive response deadline, *RAPM* Raven's Advanced Progressive, *SymSpan* Symmetry Span, *RotSpan* Rotation Span

Latent Factor	Task	Loading	95% CI	SE	*z*	*p*
AC	Antisaccade	0.704	0.550–0.857	***	0.078	8.992
AC	SACT	0.423	0.266–0.580	***	0.080	5.284
AC	StroopDL	-0.444	-0.596–-0.291	***	0.078	-5.698
Gf	LetterSets	0.641	0.528–0.754	***	0.058	11.099
Gf	NumberSeries	0.657	0.545–0.769	***	0.057	11.498
Gf	RAPM	0.728	0.625–0.831	***	0.053	13.836
WMC	OSpan	0.558	0.440–0.675	***	0.060	9.303
WMC	RotSpan	0.769	0.687–0.852	***	0.042	18.242
WMC	SymSpan	0.816	0.738–0.894	***	0.040	20.582

Table S3. Correlations between the estimated factors. *AC* attention control, *Gf* fluid intelligence, *WMC* working memory capacity. Unique scores are latent factor scores residualized by removing shared variance with the other latent factors. Z indicate unique z-scores.

	AC	WMC	Gf	AC unique z	WMC unique z	Gf unique z
AC	1.000					
WMC	0.854***	1.000				
Gf	0.788***	0.854***	1.000			
AC unique z	0.508***	0.000	0.000	1.000		
WMC unique z	0.000	0.429***	0.000	-0.566***	1.000	
Gf unique z	0.000	0.000	0.508***	-0.215***	-0.566***	1.000

Computed correlation used pearson-method with listwise-deletion.
* $p < .05$; ** $p < .01$; *** $p < .001$

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