The importance of social relationships in the process of cognitive ageing

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CHAPTER 6

Comparison of cognitive functioning as measured by the Ruff Figural Fluency Test and the CogState computerized battery in a population-based study

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ABSTRACT

This study compared cognitive functioning as measured by the RFFT and the CogState. A subcohort of the LifeLines Cohort Study (N=509; (mean age (SD): 53 years (14.6)) participated in this study. Correlations between the RFFT and six subtasks of the CogState were examined. With subgroup analyses we investigated the influence of age, education, and gender. With sensitivity analyses we investigated the influence of computer experience and (physical) impairments. All correlations between RFFT and CogState were statistically significant (except between RFFT error ratio and CogState One Back Task), ranging from -0.41 to 0.27. Stratifying for age, education, and gender did not substantially influence our conclusions. Sensitivity analyses showed no substantial influence of level of computer experience or (physical) impairments. We conclude that correlations were only weak to moderate, indicating that cognitive functioning measured by the RFFT does not measure the same components of cognitive functioning as six subtasks of the CogState.

INTRODUCTION

Dementia is considered a major public health concern because of high prevalence rates and high economic and social burden[1]. Since therapeutic interventions may be most effective in the preclinical stages of dementia, early detection of cognitive impairments is important[2,3]. Currently, the clinical diagnosis of cognitive impairment or dementia is based on labor-intensive, time-consuming, and therefore very costly paper and pencil neuropsychological testing[4]. In research settings, assessment of cognitive functioning in the population may provide important contributions in identifying risk factors associated with cognitive impairments. Various cognitive tests are available to measure (changes in) cognition in the general population, of which the Mini Mental State Examination (MMSE) is possibly the most commonly used cognitive screening instrument worldwide[5]. However, the MMSE has strong ceiling effects and limited sensitivity to detect very mild cognitive impairments, which makes it a less suitable tool for younger or highly educated populations[5,6]. Computerized cognitive testing is increasingly used and may be uniquely suited as a screening tool in large studies on (change in) cognitive functioning[7]. Compared to standard neuropsychological tests, computerized testing might be more sensitive across a wider range of cognitive functioning (less floor and ceiling effects), have more precise recording of responses, and have less test-retest effects[7,8]. One such computerized cognitive battery is the CogState, which is a multi-task computerized battery measuring multiple domains of cognitive functioning and is suitable for research among people in a wide range of ages. The CogState battery has shown to have good test-retest reliability[9] and validity[10,11].

Another tool for measuring cognitive functioning is the Ruff Figural Fluency Test (RFFT)[12]. The RFFT is a paper and pencil test used in clinical care to evaluate nonverbal fluency and executive functioning[13,14]. The RFFT is shown to be sensitive to cerebral dysfunction, particularly in the right frontal lobe[14]. Furthermore, the RFFT is sensitive to early changes in cognitive function, present in young and middle-aged persons, which is valuable in large observational studies into the mechanisms of cognitive decline and dementia and it has demonstrated good test-retest reliability and inter-rater reliability[14]. For these reasons, the RFFT has been administered in the baseline assessment of the LifeLines Cohort Study (n=167 729).

Nonetheless, as scoring of the RFFT is time consuming and information on different cognitive domains was deemed valuable, the RFFT has been replaced by the CogState battery. Since the CogState measures different cognitive domains, we examined the correlations of these scores with the RFFT score reflecting nonverbal fluency and executive functioning.

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Although both RFFT scores and CogState scores have been compared to other cognitive tests on various cognitive domains, there is no study that directly compared these cognition tests with each other. Furthermore, most studies investigating the performance of the CogState or RFFT were conducted in a clinical research setting[10,19–21], whereas only few studies were conducted in the general population including individuals of all ages and educational levels[22]. To our knowledge, no previous study has investigated whether scores on the RFFT correlate to scores on the CogState in a general healthy population. Therefore, our aim is to compare cognitive functioning as measured by the RFFT to cognitive functioning measured by the CogState, among people aged 18 years and older, broadly representative for the general population of the North of the Netherlands[23], while taking into account age, education level and gender. We hypothesize that the RFFT strongly ($r > 0.50$) correlates with the executive function subtest of the CogState, and weakly ($r \leq 0.29$), with other subtests of the CogState.

METHODS

Study design

This study is based on a sub-cohort from the LifeLines Cohort Study. LifeLines is a multi-disciplinary prospective population-based cohort study examining in a unique three-generation design the health and health-related behaviors of 167 729 persons living in the North of The Netherlands. It employs a broad range of investigative procedures in assessing the biomedical, socio-demographic, behavioral, physical and psychological factors which contribute to the health and disease of the general population, with a special focus on multi-morbidity and complex genetics. LifeLines is a facility that is open for all researchers. Information on application and data access procedure is summarized on www.lifelines.net. Details of the LifeLines study design are reported elsewhere[24,25]. Briefly, the participant recruitment and baseline assessment started in 2006 and was finished in 2013 and was performed in 12 local research sites. Baseline assessment consisted of a physical examination, cognitive functioning assessment, drawing blood samples, collecting urine samples, and self-report questionnaires regarding demographics, health status, lifestyle and psychosocial aspects. The present study includes a consecutive series of participants aged 18 years and older who visited the LifeLines study location in Groningen, the Netherlands between October 22nd and November 29th 2013. In addition to the regular research program including the RFFT, participants were invited to participate in an additional visit during which the CogState battery was administered. This additional assessment took place approximately two weeks after the baseline visit by trained research assistants.

Measurements

The *RFFT* consists of five parts and each part consists of 35 identical five-dot patterns. The task is to draw as many unique designs as possible within one minute by connecting the dots in different patterns. The test has been developed as a measure of nonverbal fluency and executive functioning, defined as the ability to utilize one or more strategies that maximize response production while at the same time avoiding or minimizing response repetition[14,26]. Studies support the construct validity of the RFFT as a measure of initiation, planning and divergent reasoning. Performance on the RFFT is expressed as the total number of unique designs (the sum of all five parts, possible range: 0-175). The error ratio (i.e. the total number of perseverative errors (i.e. repetitions of designs are scored as perseverative errors) divided by the total number of unique designs[13]), is increasingly used as a measure of performance. The error ratio also reflects executive functioning, as it is an index for assessing the respondent's ability to minimize repetition while maximizing unique productions. All participants completed the RFFT under supervision of a trained research nurse.

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Administration of the *CogState* battery was conducted on a personal computer. The battery included the Groton Maze Learning Test (GMLT) with the delayed recall (GMLR) and the Brief Battery including four card tasks. The CogState subtasks are described in detail elsewhere[11,27]. Briefly, instructions for each task were presented on the screen and participants were asked to carefully read these. A supervisor stayed present during the GMLT to help the participants understand the task during the practice session. During the CogState brief battery, no supervisor was present, although participants were informed that in case they needed assistance, a supervisor would be around to help them continue the task. The tests were administered in the following order.

1. *Groton Maze Learning test (GMLT)*
   The GMLT is a hidden pathway maze learning task that measures executive function and spatial problem solving. The primary outcome measure was the total number of errors across five trails.
2. *Detection task (DET)*
   The DET is a simple reaction time task that measures psychomotor functioning and speed of processing. The primary outcome measure was reaction time (in milliseconds), which was normalized using log10 transformation.
3. *Identification task (IDN)*
   The IDN is a choice reaction task that measures visual attention. Reaction time (in milliseconds and log10 transformed) was the primary outcome measure.

4. *One Back task (OBK)*
   The OBK is a measure of attention and working memory. The primary outcome measure was the proportion of correct answers, which was normalized using arcsine transformation.
5. *One Card Learning task (OCL)*
   The OCL is a visual learning and memory task. The primary outcome measure was the proportion of correct answers, normalized using arcsine transformation.
6. *Groton Maze learning task – delayed recall (GMLR)*
   In the GMLR participants should remember and find the hidden path as identified in the GMLT. The GMLR is a measure of visual learning and memory and the primary outcome measure was the total number of errors.

After the CogState battery, participants were administered a short questionnaire evaluating the CogState. Questions concerned whether participants had experience using a computer mouse (1=never; 2=rarely; 3=occasionally; 4=regularly; 5=often), whether (physical) impairments limited them to perform the tasks (1=yes; 2=no), and whether participants experienced the CogState as stressful (1=not at all stressful; 2=a little stressful; 3=reasonably stressful; 4=fairly stressful; 5=very stressful) or tiresome (1=not at all tiresome; 2=a little tiresome; 3=reasonably tiresome; 4=fairly tiresome; 5=very tiresome).

The following participants characteristics were collected: age, gender, educational level (categorized as low (≤12 years), or high (>12 years) according to the International Standard Classification of Education (ISCED)[28]), nationality (i.e. based on the father's and mother's country of birth according to the definition of Statistics Netherlands[29]), marital status (being in a relationship or not), smoking status (never smoker, past smoker, or current smoker), alcohol use (no alcohol use, moderate alcohol use, or problematic alcohol use), physical activity (complying with the Dutch norm of at least half an hour of moderately intensive exercise at least five days a week, yes or no[30]), and the number of neurological (i.e. stroke, multiple sclerosis, epilepsy; range 0 to 3) or cardiovascular disorders (i.e. myocardial infarction, arrhythmia, heart failure, high blood pressure; range 0 to 4), diabetes (no/yes), or depression (no/yes (i.e. major or minor depression according to the Mini International Neuropsychiatric Interview (MINI)[31]).

Statistical analysis

Sample characteristics are described by displaying percentages for categorical variables, the mean (SD) for normally distributes continuous variables and the median (IQR) for not normally distributed continuous variables.

Spearman rank correlation coefficients were calculated to compare the RFFT scores (i.e. total number of unique designs and error ratio) to the scores on the six CogState subtasks. Positive correlations are interpreted as small ($r \leq 0.29$), medium ($r = 0.30$ to $r = 0.49$), or large ($r \geq 0.50$)[32]. For negative correlations the same guidelines are applied for interpretation, but in opposite directions. As both cognitive scores are influenced by age, education level, and gender[13,15,33], we conducted subgroup analyses for: a) age (18-64 years versus ≥65 years); b) education (low versus high); and c) gender. Sensitivity analyses were performed to investigate whether having little experience using a computer mouse, or being limited by (physical) impairments would alter the results and our conclusions, by excluding those participants from the analyses. IBM SPSS statistics software version 22 was used for the statistical analysis. Significance levels were set at $p<0.05$ and all tests were two-tailed.

RESULTS

Study sample

Of the 509 participants, 494 persons completed all six CogState subtasks and 485 persons completed the RFFT, leaving a total of 471 (93%) persons with complete data on all cognitive (sub)tasks for the correlational analyses. Table 1 shows the characteristics of the total sample and of the 471 persons for the correlation analyses separately. The mean age of the total study population at baseline was 53 years old (SD: 14.6; range: 18-87) and 50% were women. Most participants were Dutch (92%) and had a high education level (76%). No substantial differences were found for the total study population compared to those with complete data on all cognitive (sub)tasks.

In general, most participants experienced the CogState not as stressful at all (n=279; 60%), or a little stressful (n=178; 38%). Only few participants experienced the CogState as reasonably stressful (n=7; 2%), or fairly stressful (n=2; 0.4%). In addition, most participants experienced the CogState as not at all tiresome (n=334; 72%), or a little tiresome (n=115; 25%). Only few participants experienced the CogState as reasonably tiresome (n=14; 3%), fairly tiresome (n=2; 0.4%), or very tiresome (n=1; 0.2%).

Comparison of RFFT and CogState scores

Table 2 presents the results of the Spearman correlation coefficients between the scores on the RFFT and on the CogState. Scores on both RFFT outcomes (i.e. number of unique designs and error ratio) correlated statistically significant with scores on all six subtasks of the CogState, except for the correlation between the RFFT error ratio and the OBK task. Correlations were of medium strength between the RFFT number of unique designs and the DET task ($r = -0.39$) and the IDN task ($r = -0.38$). The strength of all other statistically significant correlations was small (i.e. $r < 0.29$).

Table 1. Baseline characteristics of study sample

	Total sample		Sample in the correlation analyses	
	N (%)[a]	N	N (%)[a]	N
Age (years), mean (SD)	53 (14.6)	509	53 (14.5)	471
Gender (female)	254 (50%)	509	232 (49%)	471
Education level		507		469
≤12 years	120 (24%)		106 (23%)	
>12 years	378 (76%)		363 (77%)	
Nationality		507		469
Dutch	468 (92%)		433 (92%)	
Other	39 (8%)		36 (8%)	
Ruff Figural Fluency Test (RFFT)				
Number of unique designs, mean (SD)	85.16 (24.37)	485	85.50 (24.18)	471
Error ratio, median (IQR)	0.09 (0.05-0.15)	485	0.09 (0.05-0.15)	471
CogState				
Groton Maze Learning (GMLT), median (IQR)	52 (41-64)	509	52 (41-64)	471
Groton Maze Learning– Delayed Recall (GMLR), median (IQR)	7 (4-10)	504	7 (4-10)	471
Detection (DET), mean (SD)	2.57 (0.17)	500	2.56 (0.17)	471
Identification (IDN), mean (SD)	2.71 (0.09)	507	2.70 (0.08)	471
One Back (OBK), mean (SD)	1.32 (0.22)	504	1.33 (0.20)	471
One Card Learning (OCL), mean (SD)	0.97 (0.13)	506	0.98 (0.13)	471
Marital status (in a relationship)		505		468
Yes	403 (80%)		374 (80%)	
No	102 (20%)		94 (20%)	
Smoking status		500		462
Never smoker	214 (43%)		201 (43%)	
Past smoker	207 (41%)		189 (41%)	
Current smoker	79 (16%)		72 (16%)	
Alcohol use		483		451
No alcohol use	70 (15%)		64 (14%)	
Moderate alcohol use	343 (71%)		324 (72%)	
Problematic alcohol use	70 (14%)		63 (14%)	
Physical activity[b]		469		438
Yes	250 (53%)		237 (54%)	
No	219 (47%)		201 (46%)	
Number of neurological disorders[c]		491		457
No disease	476 (97%)		444 (97%)	
1 disease	15 (3%)		13 (3%)	
Number of cardiovascular disorders[d]		404		375
No disease	235 (58%)		218 (58%)	
1 disease	125 (31%)		118 (32%)	
2 diseases	40 (10%)		35 (9%)	
≥3 diseases	4 (2%)		4 (1%)	
Depression (yes)	33 (7%)	495	33 (7%)	460
Diabetes (yes)	27 (5%)	507	25 (5%)	469

[a] The percentage is reported, unless otherwise indicated.
[b] Complies with the norm of at least thirty minutes of moderately intensive exercise at least five days a week.
[c] Stroke, multiple sclerosis, epilepsy.
[d] Myocardial infarction, arrhythmia, heart failure, high blood pressure.

Table 2. Spearman correlations between the RFFT and CogState of all participants aged 18 years and older with complete data on the RFFT and CogState subtasks (n=471).

	RFFT – Number of unique designs	RFFT - Error ratio	GMLT	GMLR	DET	IDN	OBK	OCL
RFFT – Number of unique designs		-0.23**	-0.28**	-0.26**	-0.39**	-0.38**	0.22**	0.21**
RFFT - Error ratio			0.28**	0.24**	0.20**	0.11**	-0.07	-0.17**
GMLT				0.73**	0.29**	0.24**	-0.16**	-0.21**
GMLR					0.26**	0.18**	-0.18**	-0.26**
DET						0.65**	-0.08	-0.14**
IDN							-0.11*	-0.13**
OBK								0.24**

RFFT: Ruff Figural Fluency Test; GMLT: Groton Maze Learning Test; GMLR: Groton Maze Learning Test – Delayed Recall; DET: Detection Task; IDN: Identification Task; OBK: One Back Task.
*p<0.05; **p<0.01.

Subgroup analyses

The results of the Spearman correlation coefficients between the scores on the RFFT and the CogState are presented in Supplemental material A through C, separately for the following subgroups:

a) *Age (18-64 years, and ≥65 years).* Among the older adults (≥65 years, n=89 (19%)), many correlations were no longer statistically significant. However, a correlation of medium strength was found between the RFFT number of unique designs and the OBK (r = 0.43) (Supplemental material A), whereas this correlation was small (r = 0.22) in the total group of participants. Among the younger participants (n=382 (81%)), correlations were comparable to the total group of participants, although the correlation between the RFFT error ratio and the IDN was no longer statistically significant.

b) *Education (low, and high).* Among the participants with low education level (n=106 (23%)), many correlations were no longer statistically significant. Among the participants with higher education levels (n=363 (77%)), correlations were comparable to the total group of participants, although the correlation between the RFFT error ratio and the IDN was no longer statistically significant (Supplemental material B).

c) *Gender.* For men (n=239 (51%)), a correlation of medium strength was found between the RFFT unique designs and the GMLT (r = -0.32) and the GMLR (r=-0.30) (Supplemental material C), whereas this correlation was small in the total group of participants. Among women (n=232 (49%)), correlations were comparable to the total group of participants, although the correlation between the RFFT error ratio and the IDN was no longer statistically significant.

Sensitivity analyses

In total, 39 of 471 participants (8%) reported to never, rarely, or occasionally have used a computer mouse. These participants were slightly older than the total sample in the correlations (mean age (SD): 59 (16.2)) and included a higher percentage of lower educated persons (56%). Excluding these participants from the analyses did not change the results substantially nor did it alter our conclusions. Fourteen of 471 participants (3%) indicated that they were limited by (physical) impairments during the CogState, due to problems with their hands (n=6), vision (n=3), hearing (n=2), or concentration (n=3). Excluding those participants from the analyses did not alter the results substantially nor did it alter the conclusions, except for the correlation between the RFFT error ratio and the IDN which was no longer statistically significant ($r = 0.09$; $p > 0.05$).

DISCUSSION

In this study, we compared cognitive functioning as measured by the RFFT to cognitive functioning measured by the CogState. We found that the RFFT significantly correlated with virtually all subtasks of the CogState, although the strength of the correlation varied. Moderate correlations were found between the RFFT number of unique designs and the DET task and the IDN task. However, the remaining correlations were weak.

To our knowledge, this is the first study that directly compared scores of the RFFT to scores of the CogState. Other studies have compared scores of the RFFT[17,34,35] or the CogState[10,19,22] to other cognitive tests, which showed, in general, also weak to moderate, or non-significant correlations.

In our study, we would have expected a stronger correlation between the RFFT and the GMLT, as both tests are considered to measure executive functioning[11,13]. However, executive functioning comprises a collection of higher-order cognitive processes, including planning, reasoning, working memory, inhibition, cognitive flexibility, decision-making, and self-monitoring[15,16]. The performance of the RFFT relies on functions as initiation, planning and divergent reasoning[14,26], but also on levels of concentration and attention, eye-hand coordination, and the use of a systematic strategy. The performance of the GMLT also relies on multiple functions in addition to executive functioning, including immediate- and short term memory for visuospatial information, and information processing speed[11]. Therefore, although both measures are considered measures of executive functioning, since executive functioning is still a broad concept and both tests rely on the use of multiple cognitive functions, they do not measure exactly the same components of the cognitive functioning. This is one explanation for the weak correlations between both tests as reflected in the results of our study. A second explanation might be that the RFFT score also reflects processing speed. Although this has not been considered previously, this hypothesis is supported by the medium correlations with the DET and IDN task which largely reflect processing speed.

A strength of the present study is the large sample size, especially compared to previous studies on these tests. Strength of the present study is that it includes a sample with a wide range of age and education level, resulting in a broad possible variance of scores. Since scores on the RFFT and the CogState are associated with age, education level, and gender[13,15,33], we investigated whether correlations between RFFT scores and CogState scores would differ between groups. The variance in scores on the cognitive tasks in our study (represented as standard deviations and interquartile ranges) was generally larger among older persons (compared to younger persons), among persons with lower education levels (compared to persons with higher education levels), and among men (compared to women). Therefore, we expected to find stronger correlations between the RFFT and the CogState among these subgroups[32]. However, our subgroup analyses for age, education level, or gender did not show substantially different results nor did it alter our conclusions. One possible explanation for this could lie in the study design. Participants were invited for an additional visit during which the CogState was administered. Persons with cognitive limitations are therefore less likely to participate in this study because of the extra burden of an additional visit. Moreover, previous studies showed that in general, individuals with higher age, lower socioeconomic status, with chronic diseases, or with lower levels of functioning, are less likely to participate in large population based cohort studies like LifeLines[23]. However, when comparing the scores on the RFFT and on the four CogState brief battery tasks of our study to scores from other studies including healthy controls, we find comparable scores[10,13,15,27]. Furthermore, we performed sensitivity analyses to investigate the effect of computer experience on performance of the CogState. Although participants with little experience using a computer mouse were slightly older and had a lower education level compared the total sample, sensitivity analyses in which we excluded these participants from the analyses, did not change the results substantially nor did it alter our conclusions. This is in line with studies showing that the CogState has high acceptability and efficiency and is therefore very well usable for cognitive testing among older persons, with performance levels consistent with those observed in younger groups[8].

Our study has also some limitations. Unfortunately, we were not able to investigate the criterion validity of the RFFT and the CogState (i.e. ability of these tests to detect cases of MCI or dementia in the present sample[37]), due to the lack of a gold standard (i.e. based on international diagnostic guidelines or clinical judgment following a full assessment battery) in the present study. Furthermore, the CogState brief battery was administered unsupervised in the present study. The advantage of administration of the CogState in a clinical setting is that a supervisor can help participants understand the task during the practice session. Participants assessed in an unsupervised research setting may be more easily distracted, show sub-optimal effort and motivation, or may have lower scores due to inadequate understanding of the task[38]. However, the CogState is increasingly administered in an unsupervised or home setting[22,38,39], making it less labor-intensive and costly than a supervised clinical setting and standard pencil and paper testing. It has been shown that there were no differences in results between supervised and unsupervised settings[38]. If any, participants assessed at home performed slightly faster because they could schedule their assessment at a time they felt their freshest[22]. Therefore, it is unlikely that our unsupervised setting during the CogState brief battery influenced the results.

In conclusion, our results show that cognitive functioning as measured by the RFFT does not relate one-to-one to cognitive functioning as measured by six different subtasks of the CogState. Computerized testing such as the CogState may be very well suited for large cohort studies to assess cognitive functioning in the general population and to identify cognitive changes as early as possible, as it is a less time- and labor intensive tool. Nonetheless, based on our results, good comparison between these two methods is not possible due to low correlations. Therefore, within the LifeLines Cohort Study, a change in cognitive functioning as measured by the RFFT at baseline cannot be deduced from CogState scores during follow-up as shown by the low correlation in this cross-sectional study.

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Supplemental material A. Spearman correlations of RFFT and six tasks of CogState, separate for young (18-64) (N=382) and older (≥65) adults (N=89).

	Cognitive domain	RFFT		CogState					
		Unique designs	Error ratio	GMLT	GMLR	DET	IDN	OBK	OCL
RFFT									
Unique designs	Executive Function		-0.37**	-0.21*	-0.19	-0.15	-0.08	0.43**	0.28**
Error ratio	Executive Function	-0.16**		0.23*	0.26*	0.15	0.01	-0.11	-0.12
GMLT	Executive Function / Spatial Problem Solving	-0.23**	0.25**		0.74**	0.17	0.06	-0.03	-0.30**
GMLR	Visual Learning & Memory	-0.21**	0.20**	0.72**		0.17	0.06	-0.03	-0.30**
DET	Psychomotor Function / Speed of Processing	-0.30**	0.15**	0.26**	0.22**		0.52**	-0.07	-0.12
IDN	Visual Attention / Vigilance	-0.33**	0.05	0.22**	0.15**	0.61**		-0.05	-0.13
OBK	Attention / Working Memory	0.13*	-0.02	-0.16**	-0.19**	0.01	-0.06		0.29**
OCL	Visual Learning & Memory	0.20*	-0.17**	-0.18**	-0.23**	-0.13*	-0.11*	0.21**	

RFFT: Ruff Figural Fluency Test; GMLT: Groton Maze Learning Test; GMLR: Groton Maze Learning Test – Delayed Recall; DET: Detection Task; IDN: Identification Task; OBK: One Back Task.

*p<0.05; **p<0.01.

Younger adults (18-64) are presented in black; older adults (≥65) are presented in grey.

Supplemental material B. Spearman correlations of RFFT and six tasks of CogState, separate for low (0-12 years) (N=106) and high (>12 years) (N=363) education level.

	Cognitive domain	RFFT		CogState					
		Unique designs	Error ratio	GMLT	GMLR	DET	IDN	OBK	OCL
RFFT									
Unique designs	Executive Function		-0.14	-0.14	-0.16	-0.37**	-0.38**	0.19*	0.15
Error ratio	Executive Function	-0.19**		0.27**	0.16	0.12	-0.01	-0.13	-0.21*
GMLT	Executive Function / Spatial Problem Solving	-0.25**	0.23**		0.77**	0.19*	0.15	-0.06	-0.13
GMLR	Visual Learning & Memory	-0.22**	0.20**	0.70**		0.18	0.10	-0.04	-0.01
DET	Psychomotor Function / Speed of Processing	-0.32**	0.15**	0.26**	0.22**		0.57**	-0.04	-0.18
IDN	Visual Attention / Vigilance	-0.35**	0.08	0.23**	0.16**	0.64**		-0.07	-0.14
OBK	Attention / Working Memory	0.18**	-0.01	-0.15**	-0.18**	-0.04	-0.10		0.39**
OCL	Visual Learning & Memory	0.16**	-0.13*	-0.20**	-0.29**	-0.08	-0.10	0.16**	

RFFT: Ruff Figural Fluency Test; GMLT: Groton Maze Learning Test; GMLR: Groton Maze Learning Test – Delayed Recall; DET: Detection Task; IDN: Identification Task; OBK: One Back Task.
*p<0.05; **p<0.01.
Adults with higher education level (>12 years) are presented in black; adults with lower education level (≤12 years) are presented in grey.

Supplemental material C. Spearman correlations of RFFT and six tasks of CogState, separate for men (N=239) and women (N=232).

	Cognitive domain	RFFT		CogState					
		Unique designs	Error ratio	GMLT	GMLR	DET	IDN	OBK	OCL
RFFT									
Unique designs	Executive Function		-0.24**	-0.32**	-0.30**	-0.39**	-0.42**	0.28**	0.26**
Error ratio	Executive Function	-0.24**		0.29**	0.22**	0.26**	0.20**	-0.06	-0.17**
CogState									
GMLT	Executive Function / Spatial Problem Solving	-0.23**	0.27**		0.72**	0.33**	0.25**	-0.18**	-0.26**
GMLR	Visual Learning & Memory	-0.23**	0.25**	0.73**		0.30**	0.16*	-0.18**	-0.30**
DET	Psychomotor Function / Speed of Processing	-0.39**	0.14*	0.24**	0.23**		0.63**	-0.07	-0.20**
IDN	Visual Attention / Vigilance	-0.34**	0.02	0.24**	0.21**	0.65**		-0.09	-0.09
OBK	Attention / Working Memory	0.14*	-0.11	-0.14*	-0.17**	-0.10	-0.14*		0.20**
OCL	Visual Learning & Memory	0.14*	-0.19**	-0.16*	-0.21**	-0.07	-0.15*	0.28**	

RFFT: Ruff Figural Fluency Test; GMLT: Groton Maze Learning Test; GMLR: Groton Maze Learning Test – Delayed Recall; DET: Detection Task; IDN: Identification Task; OBK: One Back Task.

*p<0.05; **p<0.01.

Females are presented in black; males are presented in grey