**Title: PRONIA Cognitive Battery (PCB): Norms in healthy controls and comparisons between clinical groups.**

**Abstract**

The *PRONIA Cognitive Battery* (PCB) was set up within the frame of the European project *Personalised Prognostic Tools for Early Psychosis Management* (PRONIA), aiming at measuring those cognitive skills that are candidate predictors of the risk of developing psychosis. The PCB is a collection of 10 neuropsychological tests, mainly intended as reliable measures to be used in patients *Clinical high-risk* (CHR) for psychosis.

A normative study was carried out on the PCB measures collected on a sample of healthy volunteers who took part to PRONIA. The participants were recruited in six sites across five European countries and represent a diversity of social backgrounds, ages and education levels. General intelligence was also estimated. For selected PCB measure, scores were corrected for cognitive and socio-demographic possible confounders and standards were calculated in a sample of 276 healthy controls (61.6% of females, aged 25.4±6.35), providing percentile-based cut-offs for performance in *Deficit* (<5%), *Borderline* [5%, 15%), *Low-norm* [15%, 25%), *Norm* [25%, 75%], and *High-norm* (>75%) ranges.

**Keywords:**

Neuropsychology; Norms; Clinical high-risk; Prodromal state; PRONIA.

**Introduction**

Alterations of different cognitive domains were frequently observed in patients at psychosis onset [1], as well as in schizophrenia [2], in affective and non-affective psychotic disorders [3], and even before disorders onset [4]. These alterations are proved an early and core feature of the psychiatric illness [5] and consistently associate to a decline in daily living functions, work or school performance, sociality and poor outcome [1,6–8]. Additionally, they proved to be stable and present even in remission and in patients with a general functioning in the normal range [9].

Cognitive deficits were also reported in patients in at-risk to develop psychosis,[14–17], and consistently associate to higher rates of transition to psychosis [14,15,18,19]. For this reason, neurocognitive performances could represent informative features in algorithms predicting the transition to psychosis [20], especially when integrated with neuroimaging measures [21,22].

The identification of multiple predictors of transition to psychosis in at-risk mental states is within the aims of the European project *Personalised Prognostic Tools for Early Psychosis Management* (PRONIA; www.pronia.eu). The PRONIA Cognitive Battery (PCB) was created within this frame, for measuring features that, according to previous literature, could relate to psychosis and to the possible transition in individuals at-risk for psychosis [14, 21,22]. Also, the battery was thought in a cross-culturally perspective and standardized to be used in the four sites of the PRONIA Consortium: Germany, United Kingdom, Finland, Italy, and Switzerland. To this aim, the data collected on a sample drawn from the *Healthy controls* (HC) participating to PRONIA was used to calculate the standard norms to be applied to the raw measures derived from the PCB. The norms will allow for the generalized use of this tool in different populations of patients across the four European countries involved in the study.

The next paragraphs will describe the normative sample, the cognitive tests in the PCB, the assessment procedures and the analyses applied for calculating the norms.

**Materials and methods**

*Participants*

The PCB normative sample consisted of 276 healthy volunteers (61.6% of females; aged from 15 to 40, 25.4±6.35 years), participating to PRONIA as *Healthy Controls (HC)*, and that were assessed between January 2014 and March 2016 . The participants were tested in the sites of the PRONIA consortium: Ludwig Maximilian University of Munich(LMU); University of Cologne (UKK); University of Basel (UBS); University of Milan / University of Udine (UD/MI); University of Birmingham (BHAM); University of Turku (UTU).

Before entering the study, candidate participants were assessed with the *Structured Clinical Interview for DSM-IV Axis I Disorders* (SCID-I; [26,27]), the *Schizophrenia Proneness Instrument, Adult Version* (SPI-A; [28]), and the *Structured Interview for Prodromal Syndromes* / *Scale of Prodromal Symptoms* (SIPS/SOPS; [29–31]).

Also, the participants’ cognitive level was assessed by mean of two tests from the fourth version of Wechsler Adult Intelligence Scale (WAIS-4; [40]). Vocabulary and Matrix Reasoning tests were primarily selected (following: [56–58]; see also: [59–61]), with Information test optionally administered (to improve verbal-linguistic cognition estimation, in particular in non-native speaking participants). Estimation of total cognitive level (IQE) was obtained using score compensation with norms as tabulated in the WAIS-4 manual, available in all PRONIA consortium languages.

General exclusion criteria included: polydrug abuse, reported head trauma with loss of consciousness (>5 minutes), cognitive disability, or neuropsychological deficits (*e.g.*, post-traumatic); insufficient language skills, or hearing functionality (*e.g.*, to consent to participate; to perform a reliable neuropsychological assessment); and neurologic or somatic disorders potentially affecting the structure or functioning of the brain.

Also HC were excluded from the PRONIA sample if positive to life-time psychiatric disorder or at-risk mental state conditions; if they had a first grade relative with affective or non-affective psychotic disorder, or with a mood disorder; any psychopharmacological treatment, or illegal drugs consumption (in the month before screening or more than five times in the past); an estimated cognitive level ≤70 (*i.e.*, scores of: 64, 68, 70, and 70; see below).

The participants were assessed in seven centers of the PRONIA consortium: 160 with the German version of the PCB (*i.e.*, 62 in Cologne, 59 in Munich, and 39 in Basel), 47 with the Italian (*i.e.*, 34 in Udine and 13 in Milan), 42 with the English (*i.e.*, Birmingham), and 27 with the Finnish (*i.e.*, Turku) one. For the participants assessed with the Finnish version of the PCB (N=27), the *Hopkins’ Verbal Learning Test* were administered instead of the *Rey Auditory Verbal Learning Test* (see below). Education data were missing for nine HC participants, that were included in the sample (sample-wise mean substitution was used, where needed). See *Table 1* for a general description of the sample.

[ Insert *Table 1* about here ]

*PRONIA Cognitive Battery (PCB): Measures*

The tests included in the PCB were selected, based on a recent meta-analysis [14], with the goal of building a battery including those measures that seemed sensitive to alterations in at-risk mental states and tapping different cognitive domains: *prefrontal functions* (including *attention*, *working memory*, *processing speed*, and *verbal fluency*) *visuospatial/verbal memory*, and *social cognition*. The PCB construction proceeded including preferably

Tests whose translations in the PRONIA Consortium languages were available, as well as involving less verbal/linguistic material as possible, were preferred. The battery was designed to be administrable in about two hours. Nine tests were included in the final battery that were administered in a fixed order, as reported below (see *Table 2*).

[ Please, insert *Table 2* about here ]

1. *Rey-Osterrieth Complex Figure* (ROCF; [33]): Test of visuospatial constructive skills and visuospatial memory (both short- and long-term). ROCF includes three consecutive trials: *Copy* (the participant is asked to copy the presented figure); *Immediate memory* (the figure is reproduced immediately after the copy); and *Delayed memory* (the figure is reproduced again after 30 minutes). ROCF was administered in paper-and-pencil format with tablet support (*i.e.*, to show the figure and to register the time taken to complete each trial). To avoid interferences, only PCB verbal tests were administered before the Delayed memory trial. A standard scoring system was used: The figure was divided in 18 graphical elements and their reproductions were individually evaluated by a judge after the administration. The reproduction of each element was evaluated for its *accuracy* (*i.e.*, recognisability: 0, absent; 0.5, partial; 1, acceptable) and *placement* (i.e., localization with respect to the other elements: 0, absent/incorrect; 1, correct), combined to obtain a 0-2 element-score. Each trial resulted in a total score corresponding to the sum of item-scores (theoretical range: 0-36) and participant-wise proportional scores on the Copy performance were also calculated and preferred for memory trials in presenting results, to better compare participants with different graphomotor skills. Time to complete the Copy trial was also considered (although no explicit time limit was expected). To avoid repetition bias, the revised *Taylor’s complex figures* [34–36] was adopted for the second PCB form with the same participants.
2. *Diagnostic Analysis of Non-Verbal Accuracy, Affective Faces trial* (DANVA-2-AF; [37–39]): Simple socio-cognitive test, consisting in the recognition of 24 emotional face expressions (*i.e.*, classified as: ‘Happy’, ‘Sad’, ‘Angry’, or ‘Fearful’). DANVA-2-AF was administered and scored with tablet support, resulting in a 0-24 total score (number of correct responses).
3. *Auditory Digit Span, Forward & Backward trials* (ADS-F&B; *e.g.*, [40,41]): Test of verbal short-term memory and verbal working memory. In a first, *Forward*, set of trials participants listened to sequences of numbers, progressively increasing in length (16 trials, from two to nine digits), and they had to repeat them back in the same order to the examiner. In a second, *Backward*, set of trials reverse order was requested (14 trials, from two to eight digits). Numbers were presented at one digit per second rate by a recorded male voice, responses were registered by the examiner on the tablet during administration, with automatic scoring and stimuli presentation. Each condition was interrupted in case of two errors on a list of the same length. ADS-F&B resulted in a total score, corresponding to the number of correct responses (theoretical range: 0-30), and in a score for the Backward trials only (0-14), intended as verbal working memory measure. Different digits were used in the PCB form for the second assessment.
4. *Verbal Fluency, Phonemic & Semantic trials* (VF-P&S; *e.g.*, [42,43]): Test of verbal fluency. Participants were asked to produce as many words as possible within one minute. In *Phonemic* condition words should begin with a given letter (dependent on assessment language); in the *Semantic* condition names of ‘Animals’ were requested. The produced words were audio-recorded and a judge registered the number of correct responses, of repetitions, and of errors (*e.g.*, fantastic animals) after the administration. The total test scores correspond to the number of correct words produced in each condition. We also considered the number of correct words produced within the first 15 seconds, as a secondary measure of processing speed.
5. *Rey Auditory Verbal Learning Test* (RAVLT; [44,45]): Auditory verbal learning task consisting in learning a list of 15 semantically unrelated words (*List-A*) in five consecutive repetitions (*Immediate memory* trials), and in their retention over a 30-minutes time interval (*Delayed memory* trial). Before each Immediate memory trial, List-A was presented at one word per second rate by a recorded male voice. After the fifth trial, a different list (*List-B*) was presented and recalled (*Interference* trial), then participants were requested to recall List-A again, without re-presenting it (*Post-interference* trial). Since RAVLT was not available in Finnish, the revised version of the *Hopkins’ Verbal Learning Test* (HVLT-R; [46,47]) was included in the Finnish version of the PCB, and the results were separately analysed. HVLT-R includes a single 12-word list, repeated three times instead of five, without Interference and Post-interference trials. To avoid interferences, only PCB non-verbal tests were administered before the Delayed memory trial. Responses were registered by the examiner on the tablet during administration, with automatic scoring number of: *correct* words, *repetitions*, *out-of-lists* words, and *interferences* (*i.e.*, words from incorrect list; for RAVLT only). To summarize verbal learning performances in the tests, the total number of correct words in Immediate memory trials were considered, together with a measure of slope in performances. Also, we considered the number of correct words produced after the first presentation of List-A (and of List-B, for RAVLT only) as measure of short-term verbal memory, while that for Delayed memory trial (and the Post-interference one, for RALVT only) was intended as a measure of long-term verbal memory. Different word lists were used in the PCB form for the second assessment.
6. *Trail Making Task, A & B trials* (TM-A&B; [48,49]): Test of processing speed, also requiring sequencing, graphomotor capacity, visual attention and search ability, and flexibility. The test started with a simpler request (consisting in connect in sequence 25 numbered stimuli scattered on a sheet of paper; part *A*), followed by a more complex one (in which participants needed to concurrently consider two different sequences, numbers and letters; part *B*). TM-A&B was administered in paper-and-pencil format with tablet support (*i.e.*, to register the time taken to complete each part). During the test, the examiner registered any *error* (*e.g.*, connect two wrong stimuli) or rules *violation* (e.g., lift the pencil from the paper), immediately correcting participants. The main score of the test was the difference in seconds needed to complete part B and part A (switch time linked to task complexity). Time needed to complete part A was also considered, as measure of processing speed and graphomotor skills in a simple task.
7. *Continuous Perfomance Test, Identical Pairs version* (CPT-IP; [50–52]): Test of selective and sustained visual attention. The participants were asked to watch at a series of 300 four-digits number, presented at the rate of one per second, and to respond as fast as possible when the number presented is identical to the preceding one. Stimuli were constituted by: *targets* (numbers identical to the preceding one; 61 trials), *distractors* (numbers similar, but not identical, to preceding one; *e.g.*, composed by the same digits in a different order; 59 trials), and *fillers* (number not-related to the preceding one; 180 trials). Different kind of stimuli were randomly distributed in six 50-trials intervals. CPT-IP was administered and scored with tablet support. Reaction time and response list were recorded, so that each response was classifiable as: *Hit response* (response to a target), *Commission error* (false alarm response to a distractor), *Random/Distraction error* (false alarm response to a filler), *Missing response* (no-response to a target), and *Correct rejection* (no-response to a distractor or a filler). The test provided also a *Reaction time* (RT) measure, taken for Hit responses, and two *Sensitivity index* (d’) responses, for Hits on Commission errors on and for Hits on Random/Distraction errors. For RT and both d’, we also considered 50-trials slopes in performances.
8. *Self-Ordered Pointing Test* (SOPT; [53–55]): Test of short-term visuospatial memory and working memory. In this task participant were shown arrays of abstract figures and they were asked to touch a different figure at each presentation until all the figures in the array have been touched (with the array is rearranged randomly in successive presentations on a rectangular grid). Array composed by four- (2 × 2 grid), six- (2 × 3), eight- (2 × 4), and 10-figures (2 × 5) were presented three times each (presenting the same figures rearranged for each level, so that 28 figures were included). SOPT was administered and scored with tablet support. In test results, we considered for each level: the mean number of *Errors* and of *Perseverations* (number of times in which a participant touches the same figure three or more times in the same trial) in the three repetitions. For norms, the 10-figures trials were considered.
9. *Digit Symbol Substitution Test* (DSST; *e.g.*, [23,40]): Test of sustained attention, working memory, and processing speed. The participants were presented with a table univocally associating nine symbols to as many digits, together with an answer sheet listing 110 symbols, randomly arranged by rows. The task required to write the correct digit below each symbol, proceeding in order. The time limit was fixed at 90 seconds. The DSST was administered in paper-and-pencil, using tablet to give the stop signal. Test score was the difference between the number of correct responses and that of errors.

Selected variables by test are reported in *Table 2*.

The battery was implemented with *Psychology Experiment Building Language* (PEBL; in version 1.3 [65]), a platform using an *open-source* programming language that allows the presentation and execution of the tasks and data collection. The battery was administered on 10 inches tablets running Windows 7/8.

Four PCB[[1]](#footnote-1) version were developed in English, Finnish, German, and Italian.

*Statistical analyses*

Preliminarily to the norms calculation, between-group *Analyses of variance* were performed with Centre (LMU; UKK; UBS; MI/UD; BHAM; UTU) as between group factor and Sex, Age, IQ, Years of education and education problems (*i.e.*, years lost for repetitions or unplanned changes) as dependent variables, reporting *partial omega-squared* (ωp2) with its *95% confidence interval* (Ci; calculated with 1000 bootstraps) as effect-size measure. Effects were considered as: *large* when above 0.150, as *medium* if above 0.060, as *small* if above 0.010. The *Tukey’s honestly significant difference method* was applied to post-hoc comparisons of continuous variables.

Differences in sex distribution across Centers were analyzed by mean of a χ*2-test*, using Cramer’s V (VC) as effect-size measure (considered as: *large* when above 0.290, as *medium* if above 0.170, as *small* if above 0.060.).

For the CPT-IP, *Sensitivity index* (d’) was calculated as the difference between the *inverse of the cumulative normal distribution* of Hit responses and that of selected false alarms (possibly deviating from zero by 10−5, so that results could be in ±8.50 range, with positive values indicating better performances).

For tests with repeated measures (i.e. blocks of trials with increasing difficulty) *Slopes* in performances were calculated as *standardized linear regression coefficients* of the ordered measures, having range between -1 and +1, with negative Slopes indicating a worsening of performance.

In order to correct the effects of socio-demographic e general cognitive level, the selected PCB variables were inserted in *Linear models* as *dependent variable* and we introduced as *predictors*: *Sex* (with ‘Female’ as reference category; ‘Male’=1); *Age* in years at the assessment; mother *Language* (using four binary variables, since ‘German’ was considered as reference category and ‘Other-language’ category was assigned to participants with a mother language different from the used PCB version); *IQE*; and completed years of *Education*.

First, the best association between any dependent variable and continuous covariates (*i.e.*, Age, IQE, and Education) was estimated with linear models (*i.e.*, *linear*, *quadratic*, *cubic*, *inverse*, *logaritmic*, and *square root* transformations were examined). Best association was selected through *F-test* on model fits, followed byBIC comparison, preferring simplest model. Then, complete models with or without independent continuous variable transformations were similarly compared, considering multicollinearity too high for *variance inflation factors* (VIF) above five, and discussing it when VIF≥2. Finally, a *stepwise regression with backward elimination* was performed on the selected model, controlling for models BIC. For each model: *coefficient of determination* (R2), R2 adjusted with *Wherry Formula-1* (R2adj), *Akaike’s information criterion* (AIC), and BIC were reported. The final model residuals were used to obtain *Final scores* from the observed ones (below: *Uncorrected scores*).

The Final scores were used to calculate five-levels *Equivalent scores*: 0, ‘Deficit’ (<5th percentile, or >95th, depending on the desired direction of the measure); 1, ‘Borderline’ (from 5th to 15th, or from 85th to 95th); 2, ‘Low-norm’ (from 15th to 25th, or from 75th to 85th); 3, ‘Norm’ (from 25th to 75th; corresponding to the 50% of the sample); and 4, ‘High-norm’ (>75th, or <25th). Similarly, to compare on the same scale performances between-tests, *20-levels* scores were calculated (from 1 to 20; each corresponding to a range of five percentiles, with higher score corresponding to better performance), as well as *z-scores* (in standard deviation, referring to distribution of Final scores).

Analyses were conducted with R 3.5.1 [63].

**Results**

*Preliminary comparisons between Centers*

A medium size effect of the Center was observed for age (F5,270=7.69, p<0.001; KS=45.75, p<0.001; ωp2=0.108 [0.051, 0.200]), with younger participants assessed in Birmingham (all with p≤0.003, using Tukey’s method), although no differences between the other Centers emerged (all with p>0.050). A statistically significant, but small, Center effect emerged also for IQE (F5,270=4.27, p=0.001; ωp2=0.056 [0.011, 0.135]), with participants from Birmingham showing a lower score than those assessed in Finland (difference of 12.7, p=0.005) and Italy (11.5, p=0.002). Also statistically significant small size between Centers difference was observed for Years of Education (F5,261=4.39, p=0.001; ωp2=0.060 [0.010, 0.144]), with participant assessed in Italian Centers showing higher education that those from Birmingham (difference of 2.97 years, p<0.001) and Basel (2.08 years, p=0.023). Similarly, education problems (*i.e.*, years lost for repetitions or unplanned changes) were reported with different frequencies (from 8.0% in Turku, to 32.8% in Munich; χ25=14.81, p=0.011; VC=0.233).

No between Centre differences in sex distribution (χ25=1.11, p=0.954).

*Uncorrected scores*

Uncorrected scores (see *Table 3* for details) showed inhomogeneous by-Centre distributions in ROCF (medium-size for CF), VF-P&S (large for pF; medium for sF and sF1; small for pF1), RAVLT (medium for LW, LWa, LWb; small for LWp and LWd), CPT-IP (medium for hRT; small for cD), SOPT (small for Err10), and TM-A&B (medium for sTm and aTM) tests.

[ Please, insert *Table 3* about here ]

Mother language showed medium-size statistically significant effects on ROCF (CF), VF-P&S (pF and sF), and RAVLT (LW and LWb). Small-size effects were observed for VF-P (pF1), RAVLT (LWa, LWp, and LWd), CPT-IP (hRT, cD), SOPT (Err10), and TM-A&B (sTM and aTM). Female participants had better performances than males in ROCF (CF), VF-P (pF1), RAVLT (LW, LWp, and LWd), TM-A&B (sTM), and DSST (CS). Only small-size correlations were observed for age in years, with better performances of older participants than younger ones in VF-P&S (pF and sF) and CPT-IP (cD, only after inverse transformation) and of younger ones in ROCF (IM% and DM%) and RAVLT (LWd and LW, only after cubic transformation). IQE positive correlated with better performances with most of the measures, with the exception of Copy trial in ROCF (CF and tCF), slope in RAVLT learning (sLW), HVLT-R (LW, sLW, and LWa,), RT and slope measures in CPT-IP (hRT, shRT, scD, and sdD), and aberrant and implicit measures in SAT-SV (EAb, IAd, and IAb). Similarly, completed years of education showed only positive correlations with PCB performances, in: ADS-F&B (tDS and bDS), VF-P&S, RAVLT (LWb, LWp, LWd, and LW, only after inverse transformation), HVLT-R (LW, sLW, and LWa), CPT-IP (cD and rD), TM-A&B (sTM), DSST, and SAT-SV (EAd).

In ROCF, uncorrected total scores in different trials were statistically significantly different (Linear mixed-effects model: F2,546.6=958.84, p<0.001), with higher score in Copy trial (difference of 9.88 with Immediate memory trial and 9.86 with Delayed memory one, p<0.001), and no statistically significant difference between Immediate and Delayed memory ones (p=0.997). Also, no statistical significant difference was observed between IM% and DM% (F1,273=0.01, p=0.918).

In VF-P&S, Phonemic and Semantic conditions differed both in total scores (sF>pF, with 9.59 words of difference; F1,273.9=723.89, p<0.001) and in 15-seconds scores (sF1>pF1, with 3.54 words of difference; F1,273.3=385.01, p<0.001). Considering words produced every 15 seconds, an interaction between Phonemic and Semantic conditions were observed (F3,1914.4=33.32, p<0.001), with monotonically decreasing performances in both in Phonemic (all with p≤0.018) and Semantic (all with p≤0.002) condition, and more difference between conditions in 0-15 seconds (3.54) than in 45-60 seconds (1.59).

In RAVLT, recalled words of List-A showed to increment from 1st to 4th repetition (F6,1481.1=465.35, p<0.001; increasing of 4.81 words; all with p<0.001), without statistically significant difference 4th and 5th ones (p=0.546). In Post-interference trial score decrease (−0.44 words; p<0.001, compared to 5th trial), remaining stable in Delayed memory trial (p=0.960, compared to Post-interference trial). More words were recalled in 1st repetition with List-A than in Interference trial (List-B; F1,247=9.58, p=0.002; 0.44 words of difference). Similarly, in HVLT-R, recalled word increase between 1st and 3rd repetition (F3,78=71.84, p<0.001; +3.04 words; p≤0.040). However, no statistically significant difference was observed between 3rd and Delayed trial (−0.22 words; p=0.720).

In CPT-IP, considering scores in 50-trials blocks, we observed a decreasing of Hit responses (F5,1365=134.58, p<0.001; −2.42). Instead, increasing scores were observed for: False alarm with fillers (F5,1365=6.74, p<0.001; +0.32); Missed responses (F5,1365=50.46, p<0.001; +1.42); and Reaction times in Hit responses (F5,1361.1=62.32, p<0.001; +67.64), but with statistically significant differences only between 1st and 2nd block (p<0.001) and between 3rd and 4th one (p=0.040). Also, the number of Correct rejections generally increased (F5,1365=25.10, p<0.001; +0.63), but with a maximum at the 3rd block (+1.19) followed by a reduction. Finally, the number of False alarms with distractors showed a repetition effect (F5,1365=4.76, p<0.001) but with worst performances only in 3rd block (p≤0.006, compared to 2nd and 4th block). Generally, d’ with Commission errors (F5,1365=16.88, p<0.001) showed better performances in 1st and 3rd blocks (with p<0.001, compared to adjacent blocks) and no statistically significant difference between 4th, 5th, and 6th blocks (all with p≥0.721). Instead, d’ with Random/Distraction errors (F5,1365=34.35, p<0.001) showed a more evident reduction (−1.63), but again with no statistically significant difference between 2nd and 3rd block (p=0.214) and between 4th, 5th, and 6th (all with p≥0.468).

In SOPT, considering for Errors both level of difficulty (*i.e.*, six to 10 figures, observing a floor effect in the four figures trials) and the three repetitions at each level, statistically significant effect was observed in correct responses for both level of difficulty (F2,2185.8=392.63, p<0.001) and repetition (F2,2185.2=4.84, p=0.008), without interaction (p=0.291). Performances slightly improved at every level from 1st to 3rd repetition (with statistically significant differences only between 1st and 3rd repetition, p=0.049) and higher score in 10-figures trials. Instead, Perseveration number increase with number of figures (F2,2186.7=25.84, p<0.001), without statistically significant differences between repetitions (F2,2185.2=2.20, p=0.111).

*Final scores*

Initial models were not statistically significant so that measures did not need correction for: tCF (p=0.240; R2=0.038, R2adj=0.009; AIC=3309.8, BIC=3345.7), sLW (p=0.562; R2=0.024, R2adj=−0.005; AIC=−106.8, BIC=−75.2), hRT (p=0.087; R2=0.050, R2adj=0.021; AIC=2979.9, BIC=3015.9), shRT (p=0.899; R2=0.013, R2adj=−0.017; AIC=333.8, BIC=369.8), scD (p=0.801; R2=0.017, R2adj=−0.013; AIC=340.6, BIC=376.6), sdD (p=0.263; R2=0.037, R2adj=0.007; AIC=313.1, BIC=349.1), Per10 (p=0.366; R2=0.032, R2adj=0.003; AIC=188.5, BIC=224.6), EAb (p=0.412; R2=0.030, R2adj=0.001; AIC=2061.9, BIC=2097.9), IAd (p=0.806; R2=0.017, R2adj=−0.013; AIC=−244.5, BIC=−208.5), and IAb (p=0.529; R2=0.026, R2adj=−0.003; AIC=−416.8, BIC=−380.8)

Considering final scores, Centers effects were substantially reduced where corrections were used. In final scores, medium-size effect were observed for CPT-IP and TM-A&B reaction times (respectively, aTM: F5,262=4.91, p<0.001; ωp2=0.068 [0.019, 0.152], LMU>UKK, p<0.001, and BHAM>UKK, p=0.011), while small-size effects resulted for ROCF (CF: F5,263=3.77, p=0.003; KS=12.90, p=0.024; ωp2=0.049 [0.001, 0.130], with UKK>LMU, p<0.001), VF-S (sF: F5,269=2.48, p=0.032; ωp2=0.026 [−0.005, 0.093], with UKK>UBS, p<0.001; sF1: F5,269=4.26, p=0.001; ωp2=0.056 [0.010, 0.137], with UKK>UBS, p<0.001, and LMU>UBS, p=0.041), and TM-A&B (sTM: F5,262=2.26, p=0.049; KS=12.20, p=0.032; ωp2=0.023 [−0.012, 0.096], with LMU>UBS, p=0.014). In ROCF, no Centre effect was observed using similar corrections in total scores of Immediate (p=0.954) and Delayed (p=0.124) memory trials.

High multicollinearity was observed in initial model of pF and sF for participants’ age in years (both with VIF=2.03), and for completed years of education (VIF=2.04). Thus, predictive value of age could be inflated of the 50.7% and that of education of the 51.0%. In final models, used for corrections, age was excluded and multicollinearity resulted acceptable (all coefficients had VIF≤1.13).

For each variable, linear models’ coefficients and selection are detailed in Supplementary materials, together with correction formulas and values to calculate Equivalent scores, 20-levels scores, and z-scores.

**Abbreviations**

**ADS-F&B:** *Auditory Digit Span, Forward & Backward trials*; **AIC:** Akaike’s information criterion; **BHAM:** University of Birmingham (Birmingham, United Kingdom); **BIC:** Bayesian information criterion; **Ci:** Confidence interval; **CPT-IP:** *Continuous Perfomance Test, Identical Pairs version*; **d’:** Sensitivity index; **DANVA-2-AF:** *Diagnostic Analysis of Non-Verbal Accuracy, Affective Faces trial*; **DSST:** *Digit Symbol Substitution Test*; **HVLT-R:** *Hopkins Verbal Learning Test, Revised*; **IQE:** Estimated total cognitive level; **KS:** Kruskal-Wallis rank sum test parameter; **LMU:** *Ludwig-Maximilians-Universität München*, University of Munich (Munich, Germany); **MI:** *Università degli Studi di Milano*, University of Milan (Milan, Italy); **PCB:** PRONIA Cognitive Battery; **PEBL:** Psychology Experiment Building Language, version 1.3; **PRONIA:** Personalised Prognostic Tools for Early Psychosis Management; **r:** Pearson’s coefficient of correlation (linear association); **R2:** Coefficient of determination; **R2adj:** Coefficient of determination adjusted with Wherry Formula-1; **RAVLT:** *Rey Auditory Verbal Learning Test*; **ROCF:** *Rey-Osterrieth Complex Figure*; **RT:** Reaction time; **SAT-SV:** *Salience Attribution Task, Short Version*; **SCID-I:** *Structured Clinical Interview for DSM-IV Axis I Disorders*; **Sd:** Standard deviation; **SIPS:** *Structured Interview for Prodromal Syndromes*; **SOPS:** *Scale of Prodromal Symptoms*; **SOPT:** *Self-Ordered Pointing Test*; **SPI-A:** *Schizophrenia Proneness Instrument, Adult Version*; **TM-A&B:** *Trail Making Task, A & B trials*; **UBS:** *Universitäre Psychiatrische Kliniken Basel*, University of Basel (Basel, Switzerland); **UD:** *Università degli Studi di Udine*, University of Udine (Udine, Italy); **UKK:** *Universitätsklinikum Köln*, University of Cologne (Cologne, Germany); **UTU:** Turun Yliopisto, University of Turku (Turku, Finland); **VAS:** Visual analogue scale (from 0% to 100%); **VC:** Cramer’s V; **VF-P&S:** *Verbal Fluency, Phonemic & Semantic trials*; **VIF:** Variance inflation factors; **WAIS-4:** *Wechsler Adult Intelligence Scale, 4th edition*; ω**p2:** Partial omega-squared.

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**Tables**

*Table 1.* Sample by recruitment Centre. Age and education were reported in years. In language, other refers to participants assessed with a version of the PCB different from their mother language. Percentages of education problems (*i.e.*, years lost due to repetitions or unexpected changes) were also reported.

CAPTION: **BHAM:** University of Birmingham; **IQE:** Estimated cognitive level; **LMU:** University of Munich; **Max:** Maximum observed value; **min:** Minimum observed value; **N:** Number of observation; **Sd:** Standard deviation; **UBS:** University of Basel; **MI/UD:** University of Milan / University of Udine; **UKK:** University of Cologne; **UTU:** University of Turku.

| Centre | N (F %) | Age  Mean±Sd [min, Max] | Language  (other), N | Education and problems  Mean±Sd [min, Max], % | IQE  Mean±Sd [min, Max] |
| --- | --- | --- | --- | --- | --- |
| **BHAM** | 42 (64.3%) | 20.6±4.94 [16, 40] | 8 | 14.0±2.17 [11, 20], 16.7% | 105.1±12.58 [77, 130] |
| **LMU** | 59 (62.7%) | 26.5±6.51 [15, 40] | 4 | 15.4±3.24 [9, 23], 32.8% | 111.9±15.20 [81, 142] |
| **MI/UD** | 47 (63.8%) | 27.1±6.71 [15, 40] | 0 | 16.9±3.46 [9, 25], 8.5% | 116.6±15.49 [71, 154] |
| **UBS** | 39 (64.1%) | 25.6±5.58 [18, 39] | 5 | 14.8±3.22 [5, 21], 28.2% | 109.8±13.03 [85, 144] |
| **UKK** | 62 (58.1%) | 25.2±5.68 [16, 39] | 2 | 15.8±3.07 [10, 23], 16.1% | 109.7±13.35 [81, 142] |
| **UTU** | 27 (55.6%) | 28.1±6.29 [19, 39] | 0 | 15.6±2.56 [11, 22], 8.0% | 117.7±15.21 [92, 157] |
| *Total* | 276 (61.6%) | 25.4±6.35 [15, 40] | 19 | 15.5±3.15 [5, 25], 19.4% | 111.4±14.59 [71, 157] |

*Table 2.* PCB selected variables by test.

CAPTION: **ADS-F&B:** *Auditory Digit Span, Forward & Backward trials*; **CPT-IP:** *Continuous Perfomance Test, Identical Pairs version*; **DANVA-2-AF:** *Diagnostic Analysis of Non-Verbal Accuracy, Affective Faces trial*; **DSST:** *Digit Symbol Substitution Test*; **HVLT-R:** *Hopkins’ Verbal Learning Test, revised version*; **L:** Lower scores correspond to a better performance; **RAVLT:** *Rey Auditory Verbal Learning Test*; **ROCF:** *Rey-Osterrieth Complex Figure*; **RT:** Reaction time; **SAT-SV:** *Salience Attribution Task, Short Version*; **SOPT:** *Self-Ordered Pointing Test*;**TM-A&B:** *Trail Making Task, A & B trials*; **VAS:** Visual analogue scale (*i.e.*, subjective evaluation from 0% to 100%); **VF-P&S:** *Verbal Fluency, Phonemic & Semantic trials*.

| Test  (order) | Variable | | Measure  [range] |
| --- | --- | --- | --- |
| **ROCF**  (1st) | **CF** | Total score (sum of item scores) in the *Copy* trial. | Decimal  [0.5, 36] |
| **tCF** | Time needed to complete the *Copy* trial. | Seconds  [≥5] L |
| **IM%** | Proportion of score in the *Immediate memory* trial on CF. | Decimal  [0, 72] |
| **DM%** | Proportion of score in the *Delayed memory* trial on CF. | Decimal  [0, 72] |
| **DANVA-2-AF**  (2nd) | **EM** | Number of correctly recognized emotions. | Integer  [0, 24] |
| **ADS-F&B**  (3rd) | **DS** | Sum of correct responses in the *Forward* and *Backward* trials. | Integer  [0, 30] |
| **bDS** | Correct responses in the *Backward* trials. | Integer  [0, 14] |
| **VF-P&S**  (4th) | **pF** | Number of correct words in the *Phonemic* condition. | Integer  [≥0] |
| **pF1** | Number of correct words within 15 seconds in the *Phonemic* condition. | Integer  [≥0] |
| **sF** | Number of correct words in the *Semantic* condition. | Integer  [≥0] |
| **sF1** | Number of correct words within 15 seconds in the *Semantic* condition. | Integer  [≥0] |
| **RAVLT**  (5th)  *Non-Finnish versions.* | **LW** | Number of List-A words remembered in the *Immediate memory* trials (from the 1st to the 5th trial). | Integer  [0, 75] |
| **sLW** | Learning: Slope in List-A words remembered in the *Immediate memory* trials (from the 1st to the 5th trial). | Decimal  [−1, 1] |
| **LWa** | Number of List-A words remembered in the 1st *Immediate memory* trial (corresponding to the 1st trial). | Integer  [0, 15] |
| **LWb** | Number of List-B words remembered in the *Interference* trial (corresponding to the 6th trial). | Integer  [0, 15] |
| **LWp** | Number of List-A words remembered in the *Post-interference* trial (corresponding to the 7th trial). | Integer  [0, 15] |
| **LWd** | Number of List-A words remembered in the *Delayed memory* trial (corresponding to the 8th trial). | Integer  [0, 15] |
| **HVLT-R**  (5th)  *Finnish version.* | **LW** | Number of words remembered in the *Immediate memory* trials (from the 1st to the 3rd trial). | Integer  [0, 36] |
| **sLW** | Learning: Slope in words remembered in the *Immediate memory* trials (from the 1st to the 3rd trial). | Decimal  [−1, 1] |
| **LWa** | Number of words remembered in the 1st *Immediate memory* trial (corresponding to the 1st trial). | Integer  [0, 12] |
| **LWd** | Number of words remembered in the *Delayed memory* trial (corresponding to the 4th trial). | Integer  [0, 12] |
| **TM-A&B**  (6th) | **sTM** | Difference between time needed to complete parts *B* and *A*. | Seconds  [≥0] L |
| **aTM** | Time needed to complete part A. | Seconds  [≥5] L |
| **CPT-IP**  (7th) | **hRT** | Reaction time in *Hit responses*. | Milliseconds  [25, 1000] L |
| **cD** | Sensitivity index (d’) considering *Commission errors*. | Decimal  [−8.5, +8.5] |
| **dD** | Sensitivity index (d’) considering *Random/Distraction errors*. | Decimal  [−8.5, +8.5] |
| **shRT** | Slope in Reaction time in *Hit responses*, every 50 trials. | Decimal  [−1,1] |
| **scD** | Slope in the sensitivity index (d’) for *Commission errors*, every 50 trials. | Decimal  [−1,1] |
| **sdD** | Slope in the sensitivity index (d’) for *Random/Distraction errors*, every 50 trials. | Decimal  [−1,1] |
| **SOPT**  (8th) | **Err10** | Mean number of Errors in the three 10-figures trials. | Decimal  [0, 9] |
| **Per10** | Mean number of *Perseverations* in the three *10-figures* trials. | Decimal  [0, 8] L |
| **DSST**  (9th) | **CS** | Number of correct responses. | Integer  [−110, 110] |
| **SAT-SV**  (10th) | **EAd** | Explicit *Adaptive salience*: Difference between mean VAS in *Rewarded* categories and in *Non-rewarded* ones. | Integer  [−100, 100] |
| **EAb** | Explicit *Aberrant salience*: Absolute value of the difference between mean VAS in *Non-rewarded* categories and in *Rewarded* ones. | Integer  [−100, 100] L |
| **IAd** | Implicit *Adaptive salience*: Difference in mean RT in *Rewarded* categories and *Non-rewarded* ones (using RT in individual z-scores). | Decimal  [z-score] |
| **IAb** | Implicit *Aberrant salience*: Absolute value of the difference in mean RT in *Non-rewarded* categories and *Rewarded* ones (using RT in individual z-scores). | Decimal  [z-score] L |

*Table 3.* Uncorrected scores. For continuous predictors, correlations using linear and best transformed measures are reported.

CAPTION: **[0.5]:** Correlation for square root transformation; **[**−**1]:** Correlation for inverse transformation; **[1]:** Correlation without transformation (linear); **[2]:** Correlation for quadratic transformation; **[3]:** Correlation for cubic transformation; **[Ln]:** Correlation for logarithmic transformation; **F:** Females score; **IQE:** Estimated cognitive level; **K:** Kurtosis of the distribution; **Large:** Large effect-size; **M:** Males score; **Max:** Maximum observed value; **Medium:** Medium effect-size; **min:** Minimum observed value; **N:** Number of observation; **nss:** Not statistically significant; **r:** Pearson’s coefficient of correlation (linear association); **Sd:** Standard deviation; **Sk:** Skewness of the distribution; **Small:** Small effect-size.

| Test | Variable | N  (%) | Mean±Sd  [min, Max] | Sk,  K | Centre | Language | Sex | Age | IQE | Education |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **ROCF** | **CF** | 269  (97.5%) | 34.6±1.90  [24.0, 36.0] | −1.87,  +4.53 | Medium | Medium | F>M | nss | +0.146[1],  −0.169[−1] | nss |
| **tCF** | 269  (97.5%) | 230.4±111.86  [56.9, 896.0] | +2.22,  +7.38 | nss | nss | nss | nss | nss | nss |
| **IM%** | 269  (97.5%) | 0.71±0.153  [0.22, 1.26] | −0.44,  +0.42 | nss | nss | nss | −0.167[1],  −0.168[0.5] | +0.223[1] | nss |
| **DM%** | 269  (97.5%) | 0.71±0.143  [0.28, 1.00] | −0.59,  +0.07 | nss | nss | nss | −0.138[1] | +0.302[1] | nss |
| **DANVA-2-AF** | **EM** | 275  (99.6%) | 19.5±2.07  [13, 23] | −0.45,  −0.19 | nss | nss | nss | nss | +0.321[1],  +0.321[2] | nss |
| **ADS-F&B** | **tDS** | 275  (99.6%) | 17.8±3.83  [9, 28] | +0.09,  −0.33 | nss | nss | nss | nss | +0.311[1],  −0.316[−1] | +0.197[1],  +0.199[Ln] |
| **bDS** | 275  (99.6%) | 7.9±2.48  [3, 14] | +0.18,  −0.46 | nss | nss | nss | nss | +0.287[1],  −0.292[−1] | +0.188[1],  −0.199[−1] |
| **VF-P&S** | **pF** | 274  (99.3%) | 15.6±5.08  [4, 31] | +0.60,  +0.34 | Large | Medium | nss | +0.216[1],  −0.261[−1] | +0.300[1],  +0.304[Ln] | +0.287[1] |
| **pF1** | 274  (99.3%) | 6.5±2.07  [1, 12] | +0.29,  −0.27 | Small | Small | F>M | nss | +0.243[1],  −0.259[−1] | +0.252[1] |
| **sF** | 275  (99.6%) | 25.2±5.78  [10, 40] | +0.05,  −0.03 | Medium | Medium | nss | +0.179[1],  −0.219[−1] | +0.423[1],  −0.428[−1] | +0.309[1] |
| **sF1** | 275  (99.6%) | 10.0±2.64  [4, 20] | +0.23,  +0.39 | Medium | nss | nss | nss | +0.249[1],  +0.251[3] | +0.181[1],  +0.184[Ln] |
| **RAVLT** | **LW** | 247  (89.5%) | 60.8±7.52  [41, 74] | −0.49,  −0.34 | Medium | Medium | F>M | nss[1],  −0.168[3] | +0.322[1],  −0.327[−1] | nss[1],  −0.172[−1] |
| **sLW** | 247  (89.5%) | 0.78±0.191  [−0.35, 1.00] | −2.30,  +7.72 | nss | nss | nss | nss | nss | nss |
| **LWa** | 247  (89.5%) | 8.7±2.47  [0, 14] | +0.18,  −0.32 | Medium | Small | nss | nss | +0.273[1],  +0.276[Ln] | nss |
| **LWb** | 247  (89.5%) | 8.2±2.45  [0, 15] | +0.25,  +0.00 | Medium | Medium | nss | nss | +0.259[1],  −0.267[−1] | +0.126[1],  −0.133[−1] |
| **LWp** | 247  (89.5%) | 13.2±1.94  [7, 15] | −1.14,  +0.67 | Small | Small | F>M | nss | +0.242[1],  −0.248[−1] | +0.138[1],  −0.172[−1] |
| **LWd** | 247  (89.5%) | 13.1±2.12  [0, 15] | −2.02,  +6.49 | Small | Small | F>M | −0.148[1],  −0.209[3] | +0.281[1],  +0.282[Ln] | +0.125[1],  −0.144[−1] |
| **HVLT-R** | **LW** | 27  (9.8%) | 30.8±2.87  [23, 36] | −0.63,  +0.54 | - | - | nss | nss | nss | +0.538[1],  +0.543[2] |
| **sLW** | 27  (9.8%) | 0.85±0.264  [0.00, 1.00] | −2.51,  +5.14 | - | - | nss | nss | nss | −0.525[1],  −0.595[3] |
| **LWa** | 27  (9.8%) | 8.4±1.60  [6, 12] | +0.48,  −0.33 | - | - | nss | nss | nss | +0.606[1],  +0.624[3] |
| **LWd** | 27  (9.8%) | 11.3±1.26  [7, 12] | −2.03,  +3.67 | - | - | nss | nss | +0.454[1],  −0.489[−1] | nss |
| **CPT-IP** | **hRT** | 271  (98.2%) | 527.5±58.54  [380.9, 694.1] | +0.25,  −0.09 | Medium | Small | nss | nss | nss | nss |
| **shRT** | 271  (98.2%) | 0.37±0.435  [−0.75, 0.99] | −0.76,  −0.29 | nss | nss | nss | nss | nss | nss |
| **cD** | 271  (98.2%) | 1.94±0.776  [−0.09, 5.29] | +0.52,  +0.81 | Small | Small | nss | nss[1],  −0.143[−1] | +0.244[1] | +0.258[1],  +0.265[Ln] |
| **rD** | 271  (98.2%) | 3.58±1.267  [1.16, 8.53] | +0.86,  +0.69 | nss | nss | nss | nss | +0.181[1],  +0.183[3] | +0.142[1],  +0.145[Ln] |
| **scD** | 271  (98.2%) | −0.20±0.442  [−0.94, 0.93] | +0.48,  −0.65 | nss | nss | nss | nss | nss | nss |
| **sdD** | 271  (98.2%) | −0.31±0.424  [−0.96, 0.89] | +0.66,  −0.22 | nss | nss | nss | nss | nss | nss |
| **SOPT** | **Err10** | 273  (98.9%) | 1.36+-0.886  [0.00, 3.67] | 0.39  −0.52 | small | small | nss | nss | −0.379[1], −0.379[0.5] | nss |
| **Per10** | 273  (98.9%) | 0.28±0.335  [0.00, 1.67] | +1.32,  +1.89 | nss | nss | nss | nss | −0.141[1],  −0.142[2] | nss |
| **TM-A&B** | **sTM** | 268  (97.1%) | 29.29±15.786  [1.54, 103.49] | +1.22,  +2.44 | Medium | Small | M>F | nss | −0.275[1],  −0.276[Ln] | −0.176[1],  −0.179[2] |
| **aTM** | 268  (97.1%) | 27.65±8.929  [12.04, 63.00] | +0.90,  +0.85 | Medium | Small | nss | nss | −0.296[1],  +0.309[−1] | nss |
| **DSST** | **CS** | 276  (100.0%) | 65.0±10.38  [42, 105] | +0.45,  +0.36 | nss | nss | F>M | nss | +0.348[1],  −0.356[−1] | +0.129[1],  −0.174[−1] |
| **SAT-SV** | **EAd** | 271  (98.2%) | 46.41±30.470  [−32.50, 100.00] | −0.41,  −0.89 | nss | nss | nss | nss | +0.298[1],  +0.303[Ln] | +0.168[1],  +0.169[0.5] |
| **EAb** | 271  (98.2%) | 10.36±10.652  [0.00, 55.00] | +1.37,  +1.92 | nss | nss | nss | nss | nss | nss |
| **IAd** | 271  (98.2%) | 0.00±0.150  [−0.55, 0.68] | +0.17,  +2.39 | nss | nss | nss | nss | nss | nss |
| **IAb** | 271  (98.2%) | 0.10±0.110  [0.00, 0.89] | +2.39,  +9.96 | nss | nss | nss | nss | nss | nss |

1. The Matrix Reasoning, Vocabulary and Information sub-tests from the WAIS-4 were administered as part of the cognitive evaluation using the original materials provided by the publisher. [↑](#footnote-ref-1)