Novel cognitive factor structure revealed by computerized neuropsychological assessment

Background.
Traditional neuropsychological batteries generate relatively few performance scores per test, limiting the dimensionality of factor analytic models of cognition. Computerized tests can quantify performance more exhaustively and include process-level metrics (e.g., speech and language biomarkers, etc.) that may alter factor analytic solutions.

Methods. We analyzed the performance of 1915 participants (mean age 53 years, range 18–89, 57% female, 37% White, 23% Black, 18% Asian, 22% other race/ethnicity, 26% college educated) who underwent a 2.5-hour telemedically-proctored at-home assessment with 22 subtests of the California Cognitive Assessment Battery (CCAB), generating 105 measures of accuracy, response time, and speech-language biomarkers. Measures were grouped into five cognitive domains based on correlation structure, with each domain divided into paired subclusters to cross-validate factor loadings. Domains included Executive Function (EF), Episodic Memory (EM), Lexical/Story processing (LS), Processing Speed (PS), and Speech Fluency (SF). Two datasets were examined: (1) unregressed z-scores, and (2) residualized z-scores regressing test scores on ten demographic predictors.

Results.
Figure 1 shows the subcluster correlation matrices for uncorrected and residualized scores. Exploratory factor analysis yielded a 5-factor solution for both datasets. Figure 2 presents the resulting oblique bifactor models with g and four independent subfactors (PS, EM, LS and SF). Executive Function (EF) measures loaded almost exclusively on g, with minimal residual domain-specific variance. The model demonstrated excellent fit for both raw and residualized scores (CFI = 0.97 for both; RMSEA = 0.08, 0.06; SRMR = 0.035, 0.027). Covariances between PS and SF (r = 0.34–0.42) and between EM and LS (r = 0.13–0.28) strengthened after residualization, suggesting shared processing demands. Figure 3 shows the expected effects of age and vocabulary on factors identified in the unregressed solution.

Conclusion.
Comprehensive performance measures from computerized testing expand the measurable cognitive phenotype and reveal factor structures unobserved in traditional neuropsychological batteries. These include separable speech fluency and lexical/story processing factors. In contrast, executive control processes are largely embedded within general cognitive ability. Comprehensive automated scoring may improve the understanding of early cognitive decline by separating cognitive processes conflated in conventional batteries.

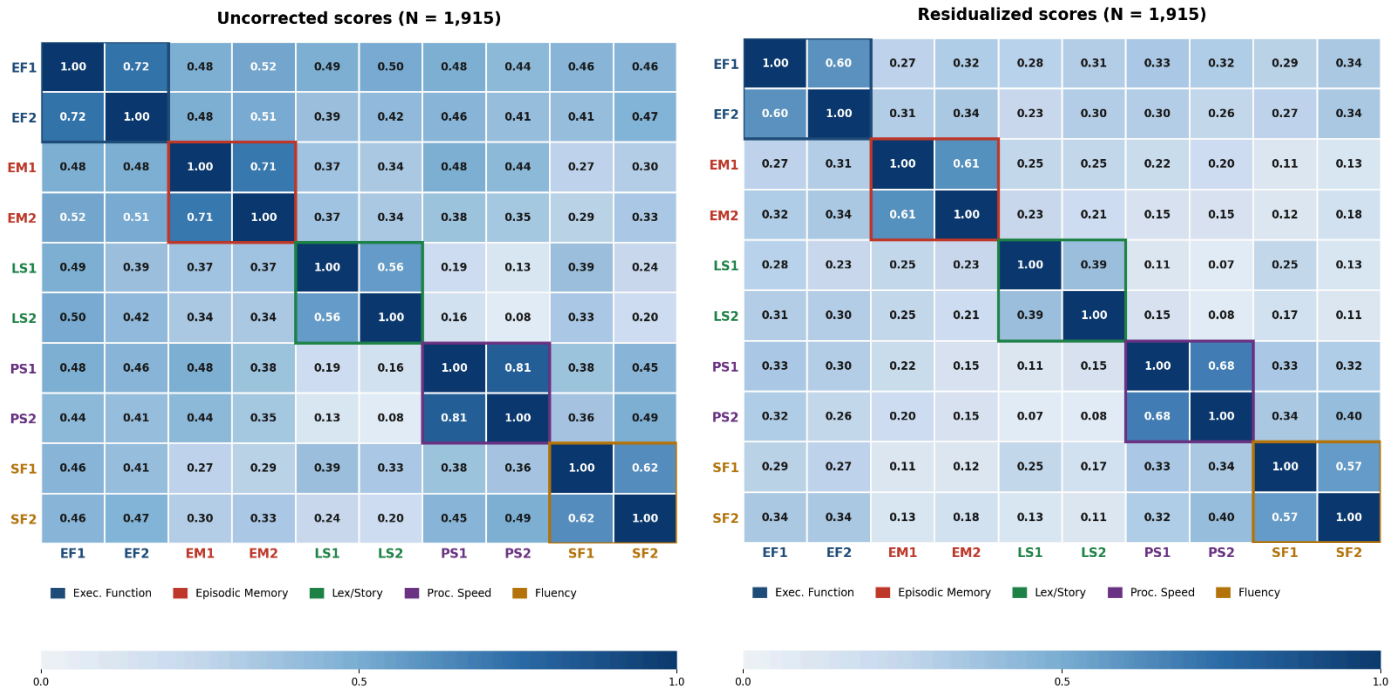

Figure 1. Correlations across domain subclusters for demographically uncorrected (left) and demographically corrected (right) scores. Each subcluster included 4-12 scores from several individual tests. After demographic correction, inter-domain correlations were reduced, with Executive Function (EF) showing the strongest cross-domain correlations in both matrices, consistent with high g loading. Z-score polarities were adjusted so that positive scores always reflected better performance.

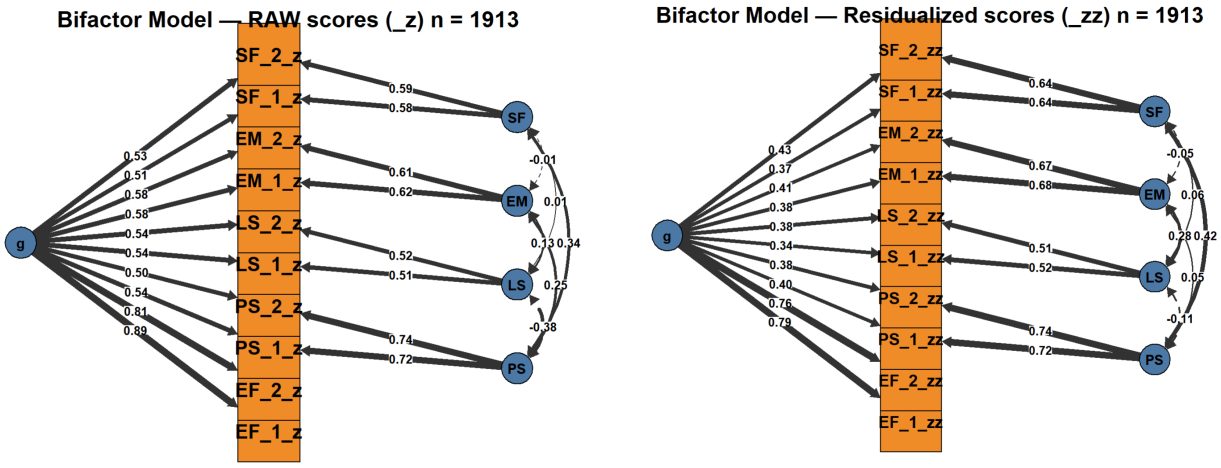

Figure 2. Similar bifactor CFA models for raw and residualized scores. Standardized loadings are shown. All measures loaded on the general factor (g), with additional loadings on domain-specific factors. Executive Function measures loaded strongly on the general factor (g), with minimal residual domain-specific variance.

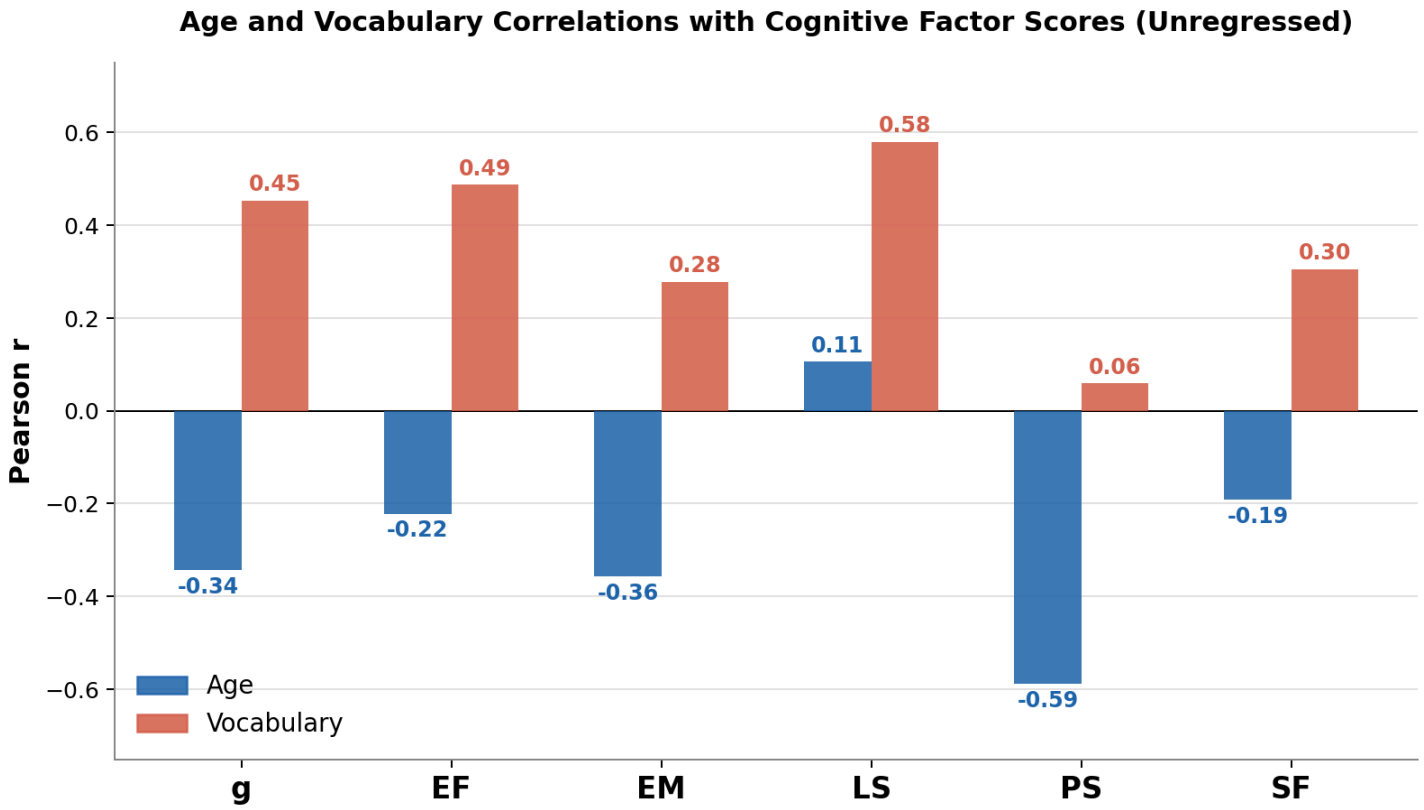

Figure 3. Age and vocabulary influenced unregressed factor scores. PS showed the strongest age decline with minimal vocabulary association, while LS showed a positive age effect and the strongest vocabulary dependence, consistent with a crystallized knowledge character.