Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Rural Living Experience as a Determinant of Rapid Naming Performance in Chinese Adults

Tianyu Gao
Qilu Hospital of Shandong University
Wei Wu
Qilu Hospital of Shandong University
Yapeng Liu
Qilu Hospital of Shandong University
Zhe Wang
Shandong University of Traditional Chinese Medicine
Anna Yao
University of California, San Francisco
Chen Chen
Qilu Hospital of Shandong University
Yuexin Ma
Qilu Hospital of Shandong University
Yifei Gao
Qilu Hospital of Shandong University
Yuwen Cheng
National Taiwan University Hospital
Yu Chen
University of California, San Francisco
Eun Sung Jee
Ewha Womans University
Katherine L. Possin
University of California, San Francisco
Elena Tsoy
University of California, San Francisco
Changshu Chen
Shandong Normal University
Maria-Luisa Gorno-Tempini
University of California, San Francisco
Boon Lead Tee
University of California, San Francisco

Guoyu Zhou

zhougy89@sdu.edu.cn

Qilu Hospital of Shandong University

Article

Keywords: Rapid Naming Test, rural living experience, naming performance, language-dependent cognition, cognitive assessment, aging

Posted Date: July 8th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10177370/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

Naming performance is widely used in cognitive assessment but is influenced not only by neurocognitive integrity, but also by lifelong language experience. Rural living experience, a major source of environmental variation, remains underexplored despite its global relevance, with approximately 3.5 billion people living in rural areas worldwide. This raises concerns about potential bias in language-based cognitive assessment.

In this cross-sectional study, cognitively normal Chinese older adults completed a Chinese version of the Rapid Naming Test (RNT-C), alongside measures of global cognition (MMSE) and non-verbal executive function (Design Fluency). Rural living experience was operationalized as the proportion of lifetime spent in rural environments. Psychometric properties of the RNT-C were evaluated, and multivariable regression models were used to examine associations between rural residence proportion and four naming indices.

The RNT-C demonstrated good internal consistency (Cronbach's $\alpha = 0.83$). Higher lifetime rural residence proportion was independently associated with lower naming performance ($\beta = -0.27$, $p = 0.027$) and slower processing speed ($\beta = 0.53$, $p < 0.001$), with the strongest effect observed for time-constrained naming ($\beta = -0.54$, $p < 0.001$). These associations were consistent across naming indices and remained after adjustment for demographic and socioeconomic factors, but were not observed for Design Fluency ($\beta = 0.003$, $p = 0.982$) or MMSE after adjustment ($\beta = -0.22$, $p = 0.086$). Education did not significantly moderate or mediate these associations.

These findings suggest that rural living experience is associated with naming performance, with effects more prominent in language-dependent cognitive processes. They further highlight a potentially underrecognized source of bias in language-based cognitive assessment and underscore the importance of incorporating sociocultural and environmental context into test interpretation.

Highlights

• Rural living experience is associated with naming performance in older adults

• Associations are robust across RNT measures and independent of education and socioeconomic factors

• Effects are more pronounced in language-dependent than non-verbal cognitive domains

• No association is observed with non-verbal executive function

• Results highlight the role of sociocultural experience in shaping cognitive assessment outcomes

1 Introduction

Naming assessments encompass a wide range of paradigms, including confrontation naming, rapid naming, action naming, responsive naming, verbal fluency, auditory naming, tactile naming, and proper noun or category-specific naming tasks, each probing distinct aspects of lexical retrieval, semantic memory, and language processing. These paradigms are widely used in the assessment of neurological disorders, including Alzheimer's disease (AD), Primary Progressive Aphasia (PPA), and stroke[1–7]. Among these approaches, rapid naming paradigms were developed to enhance sensitivity to subtle cognitive changes by combining highly familiar stimuli with time-constrained responses[8–12]. The Rapid Naming Test (RNT) further extends this framework through the use of controlled lexical properties and multiple performance indices, enabling a more fine-grained characterization of naming ability[13–15]. As rapid naming tasks place simultaneous demands on lexical access, processing speed, attention, and response automaticity, they may be particularly sensitive to early neurocognitive dysfunction.

While naming performance may sensitively reflect neurocognitive integrity, it is also shaped by lifelong linguistic, educational, and sociocultural experiences[16]. Exposure to specific objects, literacy practices, educational systems, occupational demands, and culturally shaped patterns of language use can all influence lexical familiarity and retrieval efficiency. Consequently, naming tests often require linguistic and sociocultural adaptation to optimize diagnostic validity and ensure accurate interpretation across populations. Despite this, existing RNT studies have been conducted predominantly in highly educated, urban cohorts, raising concerns regarding their generalizability and diagnostic interpretability in more diverse populations[13,14].

Rural living experience represents a major yet underexplored source of environmental and sociocultural variation. This issue is of substantial global relevance, as approximately 3.5 billion people worldwide live in rural areas, including nearly 500 million individuals in China alone, representing one of the largest rural aging populations in the world[17]. China may be particularly well positioned to examine the cognitive effects of rurality because rural–urban differences are especially pronounced due to the country's vast geographic scale, regional economic disparities, unequal access to education and healthcare, and the historical hukou (household registration) system, which has contributed to longstanding structural separation between rural and urban populations. These factors have produced substantial variation in literacy exposure, language environment, occupational experience, and familiarity with standardized testing contexts across the lifespan. Nevertheless, most cognitive assessment tools, particularly language-based measures, have been developed and normed primarily in urban populations[18]. Applying these tools to individuals with different sociocultural and educational backgrounds may therefore introduce systematic bias, potentially compromising diagnostic accuracy and contributing to misclassification.

Rural and urban environments differ substantially in object exposure, language use, literacy opportunities, educational resources, and access to standardized linguistic input[19–22]. These differences may shape semantic representations, lexical familiarity, processing efficiency, and test-taking strategies across the lifespan. In addition, individuals with greater rural living experience may have had less lifelong

exposure to highly time-structured or speed-dependent educational and occupational settings, which could disproportionately affect performance on rapid naming paradigms that emphasize speed and automaticity. Importantly, such differences may reflect experiential shaping of cognitive systems rather than true cognitive impairment. However, prior studies examining rurality and cognition have largely relied on binary rural-urban classifications, which inadequately capture cumulative environmental exposure across the life course[23].

In this study, we developed a Chinese version of the Rapid Naming Test (RNT-C) and applied it to cognitively normal older adults of urban and rural populations. We aimed to: (1) evaluate the psychometric properties of the RNT-C; (2) examine the association between lifetime rural living exposure and naming performance across multiple RNT outcome measures; and (3) determine whether the effects of rural living experience are disproportionately expressed in language-dependent tasks relative to nonverbal cognitive measures. To address the latter question, we included a nonverbal executive function measure (Design Fluency) as a reference outcome, allowing comparison across cognitive domains[24]. We hypothesized that greater rural living exposure would independently predict poorer rapid naming performance even after adjustment for demographic and socioeconomic factors. By addressing these questions, this study provides insight into how sociocultural experience shapes cognitive assessment outcomes and highlights a potentially overlooked source of bias in language-based cognitive measures.

2 Methods

2.1 Test development

The Chinese Rapid Naming Test (RNT-C) was developed through a collaboration between researchers at Shandong University and the University of California, San Francisco. More than 130 candidate stimuli were initially selected from the English, Korean and Spanish Rapid Naming Tasks. Candidate stimuli and images were then reviewed by native Mandarin- or Cantonese-speaking neurologists, neuropsychologists, research coordinators. Stimulus selection was guided by four criteria. First, stimuli were required to demonstrate high target-name agreement of higher than 85%. Target-name agreement was evaluated through pilot testing in eight cognitively unimpaired native Mandarin- and Cantonese-speaking adults recruited from diverse Chinese-speaking regions, including Mainland China, Taiwan, the United States, and Malaysia. Participants were asked to provide the most commonly used name for each depicted object. Items that elicited substantial variability in naming, regional lexical differences, or multiple competing responses were excluded through consensus among the study team. Disagreements were resolved by majority vote and senior investigator adjudication. Second, items were selected to provide broad coverage across semantic categories, including animals (n = 15), daily objects (n = 25), food items (n = 9), electronic devices and transportation (n = 9), and other categories (n = 8). Third, items were selected to represent familiar concepts with high lexical frequency to minimize naming failures attributable to low word exposure. Word frequency estimates were obtained from the Center for Chinese

Linguistics Corpus, Peking University and the Academia Sinica Balanced Corpus. Candidate items were generally required to have a Zipf frequency greater than 5.4, indicating moderate to high lexical frequency[25,26]. Fourth, line image stimuli were selected to maximize perceptual clarity and cultural appropriateness. Images with excessive visuospatial complexity, ambiguous visual features, or regional-specific recognizability were avoided to minimize the influence of visual processing demands on naming performance. For example, objects that differed substantially in appearance or usage across regions such as mailbox or stamps were excluded or adapted. The resulting 66-item developmental version was administered for pilot testing and psychometric evaluation. Following item analysis, a final 60-item version is planned for future implementation.

2.2 Participants

This cross-sectional study consecutively recruited cognitively healthy adults aged ≥ 50 years (MMSE ≥ 27) between January and December 2025. All participants were native Chinese speakers and right-handed. All cognitive assessments were conducted by trained neurologists under standardized conditions. The study was approved by the Ethics Committee of Qilu Hospital, Shandong University (Approval No. KYLL-2026-02-040), and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants. Exclusion criteria included: (1) delirium within the past 6 months; (2) history of major neurological disorders affecting cognition, speech, or language function; (3) uncontrolled systemic or metabolic disorders; (4) alcohol or substance abuse within the past 12 months; and (5) uncorrected visual or hearing impairment.

2.3 Measures

Demographic variables

Demographic information was collected using a standardized questionnaire, including age, sex, years of education, occupation, annual income, and rural living duration. Occupation was classified according to the International Standard Classification of Occupations (ISCO) and grouped into high-level non-manual (groups 1–2), low-level non-manual (groups 3–5), and manual labor (groups 6–9). Annual income was categorized into ≤ 100,000 RMB, 100,000–200,000 RMB, and > 200,000 RMB, representing low-, middle-, and high-income households relative to contemporary household income levels in China according to data from the National Bureau of Statistics of China[27]. Rural living experience was operationalized as the cumulative number of years participants resided in rural or township areas across their lifespan. Classification of residential locations was based on the official urban–rural classification system established by the National Bureau of Statistics (NBS) of China, namely the Statistical Area Codes and Urban–Rural Classification Codes, which are implemented in accordance with the Regulations on the Statistical Classification of Urban and Rural Areas issued by the State Council of China (2008). Participants provided a lifetime residential history, and all residences were classified according to NBS criteria. Rural living duration was calculated as the total number of years spent in rural villages or non-urbanized township areas. Classification was determined based on the actual place of residence rather than household registration (hukou) status. To account for differences in age, a rural living proportion

was also calculated by dividing cumulative rural living years by current age, yielding a continuous measure of lifetime rural exposure.

Cognitive assessments

All assessments were conducted in a quiet environment by trained neurologists. In addition to the RNT, participants completed the MMSE and Design Fluency tests to provide measures of global cognition and a visually mediated executive function task.

1. RNT-C: Participants completed a developmental 66-item Chinese RNT, consisting of 60 candidate scored items and 6 additional run-in items included to familiarize participants with task procedures and response timing. Each item was presented with a maximum response window of 5 seconds. For the present preliminary analyses, performance was summarized across all 66 administered items, as item reduction and final test construction are ongoing. Outcome measures included: (1) total RNT-C score (0–66), representing the total number of correctly named items; (2) total RNT-C completion time, representing the time required to complete the entire test; (3) first-minute RNT-C score, representing the number of correctly named items within the first 60 seconds; and (4) first-minute RNT-C accuracy, representing the percentage of correct responses among all responses produced within the first 60 seconds.
2. Design Fluency[28]: To provide a nonverbal counterpart to the executive demands of the RNT, participants completed the Design Fluency subtest of the Delis–Kaplan Executive Function System (D-KEFS). Both tasks require visual processing and executive abilities; however, Design Fluency minimizes language demands and does not require lexical retrieval. Participants generated as many unique designs as possible within 60 seconds according to standardized administration procedures. The total number of valid, non-repeated designs produced was recorded (n = 84).
3. MMSE[29]: Global cognitive function was assessed using the MMSE (0–30). A score ≥ 27 was used as the inclusion criterion and for criterion validity analyses.

2.4 Statistical analysis

Descriptive statistics were used to summarize demographic, socioeconomic, and cognitive variables. Normality of continuous variables was assessed using the Shapiro-Wilk test. Normally distributed variables are presented as mean±standard deviation, and non-normally distributed variables as median and interquartile range. The internal consistency and reliability of the RNT-C were evaluated using Cronbach's αand the Spearman-Brown split-half coefficient. Criterion validity was assessed by examining correlations between RNT-C total score and MMSE and Design Fluency scores. Spearman rank correlation analyses were conducted to examine bivariate associations between RNT-C outcome measures (total score, total completion time, first-minute correct count, and first-minute accuracy) and demographic and cognitive variables, including age, sex, years of education, occupational category, household income, MMSE, and Design Fluency.

To examine the independent association between rural residence ratio and naming performance, multivariable linear regression models were constructed for each RNT-C outcome. All models were adjusted for age, sex, years of education, occupational category, and household income. Additional models were constructed using MMSE and Design Fluency scores as outcomes to assess domain specificity. Moderation analyses were performed to test whether years of education modified the association between rural residence ratio and cognitive outcomes. Both variables were mean-centred prior to constructing the interaction term. For significant interactions, simple slope analyses were conducted at − 1 SD, mean, and + 1 SD levels of education. Exploratory mediation analyses were conducted using a bootstrap approach (2,000 resamples, percentile confidence intervals) to examine whether years of education mediated the association between rural residence ratio and cognitive outcomes. Given the cross-sectional design, mediation results were interpreted cautiously as indicative of statistical rather than causal pathways.

All analyses were conducted using R (version 4.4.3) and IBM SPSS Statistics (version 27). Statistical significance was defined as a two-tailed p-value < 0.05.

3 Results

3.1 Participant characteristics

Ninety-three cognitively healthy individuals were included in the analysis. Demographic, socioeconomic, and cognitive characteristics are summarized in Table 1. The sample comprises of 37 male and 56 female participants. Median age was 55 (IQR: 53–59) years, median years of education were 11 (9–12) years, and median rural residence ratio was 0.24 (0-0.42). Median MMSE score was 29 (28–30) and median naming total score was 55 (52–59) out of a maximum of 66 items. Distributions of the four primary RNT-C outcome measures are presented in **Figure S1**.

Table 1
Demographic and clinical characteristics of the participants (*n* = 93)

Variable	(n, %) / Median (IQR) / M ± SD	Range
Age (years)	55 (53, 59)	50–78
Sex		
Male	(37, 39.8%)	
Female	(56, 60.2%)	
Years of education	11 (9, 12)	2–17
Occupational category		
Senior non-manual worker	(36, 38.7%)	
Junior non-manual worker	(25, 26.9%)	
Manual worker	(32, 34.4%)	
Annual household income (10,000 CNY)		
≤ 10	(44, 47.3%)	
10–20	(44, 47.3%)	
> 20	(5, 5.4%)	
Rural life duration (years)	12 (0, 23)	0–65
Rural residence ratio	0.24 (0.00, 0.42)	0–1
Naming total score	55 (52, 59)	38–66
Naming total time (seconds)	118 (103, 141)	59–223
First-min naming correct count	30.8 ± 10.4	9–56
First-min naming accuracy rate (%)	87.0 (80.0, 91.0)	60.0–100
MMSE	29 (28, 30)	27–30
Design Fluency	10 (8, 12)	4–19

Note. Categorical variables are presented as frequency and percentage (n, %). Continuous variables were tested for normality using the Shapiro–Wilk test; normally distributed variables are presented as mean ± standard deviation (M ± SD), and non-normally distributed variables as median and interquartile range [Q25, Q75]. IQR = interquartile range; MMSE = Mini-Mental State Examination.

3.2 Psychometric properties of the RNT-C

The RNT-C demonstrated high internal consistency (Cronbach's α = 0.83) and split-half reliability (Spearman–Brown corrected coefficient = 0.82). Naming total score was significantly and positively

correlated with MMSE score (ρ = 0.27, p = 0.009) while the correlation between naming total score and Design Fluency score did not reach statistical significance (ρ = 0.17, p = 0.125).

3.3 Effects of rural life experience on naming performance

Correlations between rural residence ratio and RNT-C outcomes

Spearman rank correlations among all key variables are presented in Supplementary **Figure S2**. Bivariate analyses revealed significant associations between rural residence ratio and all four RNT-C outcomes (Fig. 1). Rural residence ratio was negatively correlated with RNT-C total score (ρ = −0.26, p = 0.013), first-minute RNT-C correct count (ρ = −0.57, p < 0.001), and first-minute RNT-C accuracy rate (ρ = −0.24, p = 0.019), and positively correlated with RNT-C total completion time (ρ = 0.54, p < 0.001). Rural residence ratio was also negatively correlated with years of education (ρ = −0.26, p = 0.011) and MMSE (ρ = −0.22, p = 0.035), both of which were subsequently included as covariates in multivariable regression analyses.

Multivariable linear regression analyses

Multivariable linear regression analyses adjusting for sex, years of education, occupational category, household income, and MMSE demonstrated that rural residence ratio was a significant independent predictor of all four RNT-C outcomes (Supplementary **Table S1**). For RNT-C total score, rural residence ratio across its full theoretical range (purely urban, ratio = 0, to purely rural, ratio = 1) was associated with a predicted decrease of 5.29 points (B = − 5.29, SE = 2.35, β = −0.27, p = 0.027, 95% CI [− 9.95, − 0.62]). The RNT-C total score model explained 16.5% of outcome variance (adjusted R^2 = 0.165, F = 3.26, p = 0.003).

Larger effects were observed for first-minute RNT-C correct count and RNT-C total completion time. Across the full rural residence ratio range, purely rural individuals were predicted to correctly name approximately 18 fewer items in the first minute (B = − 17.46, SE = 3.44, β = −0.54, p < 0.001, 95% CI [− 24.30, − 10.63]) and take approximately 54 seconds longer to complete the task (B = 54.13, SE = 11.40, β = 0.53, p < 0.001, 95% CI [31.45, 76.80]) compared to purely urban individuals. A smaller but significant effect was observed for first-minute RNT-C accuracy rate, with purely rural individuals predicted to achieve 7.0 percentage points lower accuracy than purely urban individuals (B = − 0.070, SE = 0.033, β = −0.26, p = 0.036, 95% CI [− 0.135, − 0.005]).

Domain differences in rural life experience effects

To examine whether the effects of rural life experience were specific to RNT-C, MMSE and Design Fluency scores were analyzed as reference outcomes. Bivariate analyses showed that rural residence ratio was significantly negatively correlated with MMSE score (ρ = −0.22, p = 0.035) but not with Design Fluency score (ρ = −0.11, p = 0.343; Fig. 2).

In multivariable regression analyses, rural residence ratio was not significantly associated with Design Fluency (B = 0.14, SE = 1.34, β = 0.01, p = 0.920, 95% CI [− 2.54, 2.81]) or MMSE (B = − 0.73, SE = 0.42, β =

−0.22, p = 0.082, 95% CI [− 1.56, 0.10]) total scores after covariate adjustment. As shown in Fig. 3, the standardized effects of rural residence ratio on the four RNT-C outcomes (|β| = 0.28–0.56) were substantially larger than those on MMSE (β = −0.22, p = 0.082) and Design Fluency (β = 0.01, p = 0.920), indicating that the cognitive effects of rural life experience may be more prominent in language-dependent domains than in non-verbal or global cognitive measures.

3.4 Role of years of education

Moderation analyses tested whether years of education modified the association between rural residence ratio and each cognitive measure, with both variables mean-centred prior to constructing the interaction term. The interaction term was not statistically significant for any of the six outcomes (all p > 0.10; Supplementary **Table S2**). For illustrative purposes, simple slopes analysis revealed a consistent monotonic gradient for RNT-C outcomes: the negative association between rural residence ratio and RNT-C total score was strongest among participants with lower education (− 1 SD, 7.9 years: B = − 5.88), intermediate at mean education (11.0 years: B = − 3.98), and weakest at higher education levels (+ 1 SD, 14.1 years: B = − 2.07; Supplementary **Figure S3**). This pattern is suggestive of a possible buffering role of education but should be interpreted cautiously given the non-significant interaction term.

Complementary to the moderation analysis, bootstrap mediation analyses (2,000 resamples) adjusting for sex, occupational category, and household income showed that the indirect effects of rural residence ratio via years of education were not statistically significant for any of the six outcomes (all p ≥ 0.080; Table 2). The indirect effect for RNT-C total score was B = − 0.84 (95% Bootstrap CI [− 2.40, 0.31], p = 0.161), and the indirect effect for MMSE approached significance (B = − 0.21, 95% CI [− 0.51, 0.02], p = 0.080; proportion mediated = 21.3%). Despite non-significant indirect effects, the direct effects of rural residence ratio on all four RNT-C outcomes were statistically significant (RNT-C total score: p = 0.015; RNT-C total time: p < 0.001; first-minute RNT-C correct count: p < 0.001; first-minute RNT-C accuracy rate: p = 0.026), as were the corresponding direct effects, indicating that the effect of rural life experience on naming performance is primarily mediated through pathways other than years of education.

Table 2
Mediation analysis: years of education as mediator of the association between rural life proportion and cognitive outcomes

Outcome	Total effect B (95% CI)	Indirect effect B (95% CI)	p (indirect)	Direct effect B (95% CI)	p (direct)
RNT-C Total score	−6.43 (− 10.37, − 2.29)	−0.84 (− 2.40, 0.31)	0.161	−5.59 (− 9.73, − 1.30)	**0.015***
RNT-C Total time	60.16 (38.23, 80.60)	1.38 (− 3.86, 8.59)	0.597	58.78 (36.80, 79.86)	**< 0.001*****
First-min RNT-C correct count	−19.82 (− 27.17, − 12.89)	−0.25 (− 1.66, 1.16)	0.704	−19.58 (− 26.93, − 12.38)	**< 0.001*****
First-min RNT-C accuracy rate	−0.087 (− 0.152, − 0.024)	−0.011 (− 0.028, 0.003)	0.127	−0.076 (− 0.140, 0.011)	**0.026***
MMSE	−0.97 (− 1.67, − 0.10)	−0.21 (− 0.51, 0.02)	0.080	−0.77 (− 1.49, 0.10)	0.075
Design fluency	−0.74 (− 3.00, 1.68)	−0.60 (− 1.56, 0.07)	0.100	−0.14(− 2.57, 2.39)	0.897

Note: Mediator = years of education. All models adjusted for sex, occupational category, and household income. Indirect effects estimated via nonparametric bootstrap (2,000 resamples); 95% confidence intervals calculated using the percentile method. $p < 0.05$ considered statistically significant. *$p < 0.05$, ***$p < 0.001$

4 Discussion

In this study, we developed and evaluated a Chinese version of the Rapid Naming Test (RNT-C) and examined how rural living experience relates to naming performance in cognitively healthy older adults. The RNT-C showed good internal consistency and expected patterns of construct validity, supporting its use as a culturally adapted naming measure in Chinese populations[30,31]. More importantly, we found that rural living experience, quantified as the proportion of lifetime spent in rural environments, was consistently associated with multiple aspects of RNT-C performance. These associations remained after adjustment for demographic and socioeconomic factors. In contrast, the association with global cognitive performance was attenuated after adjustment, and no association was observed for non-verbal executive function.

Taken together, these findings suggest that rural living experience is linked to rapid naming performance in ways that are not fully explained by general cognitive ability or education level. Rapid naming is a multi-stage process involving visual recognition, semantic memory, lexical retrieval, motor speech, attention and cognitive speed[31]. Several mechanisms may explain the observed differences in rapid naming performance according to rural living experience. First, cumulative language exposure shapes semantic knowledges and lexical access throughout the lifespan[32,33]. In rural environments, access to

certain forms of linguistic input, particularly print materials and standardized language, may be more limited[19], which could influence the breadth and organization of semantic representations. Second, differences in everyday object environments may affect familiarity with specific stimulus categories, influencing both naming accuracy and response speed, particularly when test items do not equally reflect the living experiences of different populations[20,34–37]. Third, lexical retrieval efficiency may also vary according to language use patterns. Lower levels of print exposure have been linked to less efficient lexical access[16,38], while the coexistence of different Chinese languages in rural settings may increase competition during lexical selection[39]. In particular, semantic memory organization and lexical retrieval efficiency are shaped by cumulative language exposure and the familiarity with objects and concepts encountered across the life span. Individuals with greater rural living experience may be exposed to different object environments, language use patterns, and communicative contexts than those residing primarily in urban settings. These experiential differences may influence semantic organization and lexical access, thereby affecting rapid naming performance independent of underlying cognitive capacity[16,32,40].

The pattern of results across cognitive measures provides additional context for interpreting these findings. The associations of rural living experience with RNT-C outcomes were robust and consistent, whereas the association with MMSE did not remain significant after adjustment, and no association was observed for Design Fluency performance. This pattern suggests that the effects of rural living experience are more prominent in language-dependent cognitive processes than in global or non-verbal measures. One possible explanation is that the MMSE is designed to assess global cognitive functioning rather than specific language abilities. Although several MMSE items involve language processing, these contribute only a portion of the total score. Consequently, effects related to language experience may be diluted by performance in other cognitive domains, potentially explaining the weaker and non-significant association after adjustment[29]. In contrast, Design Fluency is a non-verbal task that primarily engages visuospatial and executive processes without linguistic demands[41], and therefore may be less sensitive to differences in language experience. The absence of a corresponding association with Design Fluency makes a generalized effect of processing speed or test-taking style less likely and is more consistent with mechanisms involving language experience, semantic knowledge, and lexical access.

Interestingly, the associations between rural living experience and naming performance were not explained by years of formal education. Neither moderation nor mediation analyses supported a significant role of education, suggesting that the observed associations are unlikely to be attributable to differences in educational attainment alone. Although education has been widely recognized as a key determinant of cognitive performance and cognitive reserve[42–44], it primarily reflects formal learning and may not fully capture the cumulative effects of everyday language exposure, communicative context, and sociocultural experience across the life course. In this context, rural living experience may represent a complementary dimension of sociolinguistic exposure that influences language-related cognitive processes through long-term patterns of language use and semantic engagement. Furthermore, the quality and cognitive benefits of formal education may vary across rural and urban contexts[45,46],

highlighting the limitations of using years of education alone as a proxy for life-course cognitive experience and suggesting that our null mediation finding may, if anything, underestimate the true independence of the rural living effect from educational factors.

From a methodological perspective, this study highlights the value of moving beyond simple rural–urban classifications. Conventional approaches often rely on binary indicators or current residence, which may not adequately capture the cumulative nature of environmental exposures across lifespan[47]. By using a continuous measure of lifetime rural exposure, we were able to characterize individual differences in a more nuanced way, taking into account both duration and timing of rural residence. This approach is consistent with life-course frameworks that emphasize the cumulative impact of environmental factors on cognitive outcomes[42].

These findings have important implications for the development and interpretation of naming assessments. Naming-based tests are widely used in both clinical and research settings, but their interpretation often assumes that performance primarily reflects neurocognitive status. However, our results suggest that it may also reflect life-course environmental and sociolinguistic experiences that are not fully captured by conventional demographic measures such as education. This consideration may be particularly relevant in countries where rural and urban environments differ substantially in language use, educational opportunities, and everyday experiences, and where individuals often spend much of their lives within predominantly rural or predominantly urban settings. The potential impact of these issues is considerable, given that approximately 3.5 billion people worldwide reside in rural areas, including nearly 500 million individuals in China alone[17]. Under such circumstances, lexical norms and naming stimuli derived primarily from urban populations may not fully represent the experiences of individuals with extensive rural living exposure. More broadly, many lexical databases and normative studies do not explicitly characterize the rural–urban composition of their samples, making it difficult to determine whether measures such as familiarity, frequency, and naming agreement generalize across populations with different sociolinguistic backgrounds. Future normative studies and lexical database development efforts should therefore consider environmental representativeness to improve the validity and generalizability of language assessments across diverse populations.

Several limitations should be acknowledged. First, the cross-sectional design limits causal inference, and longitudinal studies are needed to clarify how rural living experience influences cognitive trajectories over time. Second, although the sample size was sufficient for the primary analyses, it may have limited statistical power to detect weaker associations between rural living experience and RNT-C performance. Third, the mechanisms underlying the observed associations remain speculative, as factors related to language exposure, semantic knowledge, and lexical processing were not directly measured. In particular, the linguistic environments of our participants were not systematically characterized. Many individuals in China are exposed to multiple Chinese languages or regional varieties, including Mandarin, Cantonese, Hokkien, and local Shandong dialects. These languages differ substantially in their phonological, lexical, and, in some cases, syntactic characteristics, resulting in varying degrees of linguistic distance from one another. Such multilingual and multidialectal experiences may influence the

organization of semantic knowledge, lexical retrieval processes, and naming performance across the lifespan. Fourth, participants were recruited from a single province (Shandong) and findings may not generalize to other Chinese regions with different landscapes of Chinese languages, or non-Chinese-speaking populations. Finally, the RNT-C used in this study represents a developmental 66-item version. Although additional psychometric evaluation, including assessments of criterion and structural validity, remains warranted, the present findings provide initial evidence regarding the utility of the instrument and the factors associated with naming performance. Additionally, while stimuli were selected to be culturally appropriate and image familiarity was assessed through target-name agreement pilot testing, formal measurement equivalence across rural and urban groups was not established. Differential item familiarity between rural and urban groups cannot be ruled out and warrants examination in future validation work with larger and more diverse Chinese-speaking populations.

In conclusion, this study introduces the RNT-C, a culturally adapted rapid naming measure demonstrating adequate reliability and preliminary validity evidence in Chinese-speaking adults. Using this tool, we demonstrate that lifetime rural living experience is an independent determinant of verbal naming performance, affecting both naming accuracy and lexical retrieval speed in ways not explained by educational attainment, general cognitive ability, or non-verbal executive function. Together, these findings suggest that cognitive test performance is shaped not only by brain health and education, but also by the sociolinguistic and environmental experiences accumulated across the life course, underscoring the need for more contextually informed approaches to cognitive assessment.

Declarations

Funding

This study was supported by the China Original Drug Research Fund Project (Project No. 6010120030), the 2025 Milstein Medical Asian American Partnership Foundation (MMAAP) Research Award in Senior Health, and the Yantu Neurology Special Research Fund of the China International Medical Foundation (G.Z.). The funding sources had no role in the study design; data collection, analysis, or interpretation; manuscript preparation; or the decision to submit the manuscript for publication.

Acknowledgements

We sincerely thank all study participants for their time and contribution to this study.

Author Contributions

T.G. and W.W. contributed equally to this work. G.Z. and B.L.T. conceived, designed, and supervised the study. T.G., W.W., Y.L., Z.W., C.C. (Chen Chen), Y.M., and Y.G. recruited participants and collected the data. A.Y. contributed to stimulus selection and visual stimulus preparation. Y.-W.C. and Y.C. contributed to stimulus selection, statistical analysis, and data interpretation. C.C. (Changshu Chen) provided linguistic expertise and guidance on the Chinese language aspects of the study. J.E.S., K.L.P., E.T., and M.-L.G.-T.

provided scientific input, contributed to the interpretation of the findings, and critically reviewed the manuscript. T.G., W.W., G.Z., and B.L.T. analyzed and interpreted the data and drafted the manuscript. All authors reviewed the manuscript, approved the final version, and agree to be accountable for all aspects of the work.

Competing Interests

The authors declare no competing interests.

References

1. Cheung, R. W., Cheung, M. & Chan, A. S. Confrontation naming in chinese patients with left, right or bilateral brain damage. *Journal of the International Neuropsychological Society: Jins* 10, 46–53 (2004).
2. Gorno-Tempini, M. L. et al. Classification of primary progressive aphasia and its variants. *Neurology* 76, 1006–1014 (2011).
3. Hodges, J. R., Salmon, D. P. & Butters, N. The nature of the naming deficit in alzheimer's and huntington's disease. *Brain.* 114, 1547–1558 (1991).
4. Gollan, T. H. et al. The mint sprint 2.0: a picture naming test for detection of naming impairments in alzheimer's disease and in preclinical ad. *Alzheimer's & Dementia* 20, 112–123 (2023).
5. Isella, V. et al. A metabolic imaging study of lexical and phonological naming errors in alzheimer disease. *American Journal of Alzheimer's Disease & Other Dementiasr* 35, 1419625039 (2020).
6. Mckinnon, E. T. et al. Types of naming errors in chronic post-stroke aphasia are dissociated by dual stream axonal loss. *Sci. Rep.* 8, 14352 (2018).
7. Georgiou, E. et al. Naming ability assessment in neurocognitive disorders: a clinician’s perspective. *Bmc Psychiatry* 22, 837 (2022).
8. Kvitting, A. S., Wimo, A., Johansson, M. M. & Marcusson, J. A quick test of cognitive speed (aqt): usefulness in dementia evaluations in primary care. *Scand. J. Prim. Health Care* 31, 13–19 (2013).
9. Akhand, O. et al. The new mobile universal lexicon evaluation system (mules): a test of rapid picture naming for concussion sized for the sidelines. *J. Neurol. Sci.* 387, 199–204 (2018).
10. Denckla, M. B. & Rudel, R. G. Rapid ‘automatized’ naming (r.a.n.): Dyslexia differentiated from other learning disabilities. *Neuropsychologia* 14, 471–479 (1976).
11. Norton, E. S. & Wolf, M. Rapid automatized naming (ran) and reading fluency: implications for understanding and treatment of reading disabilities. *Annu. Rev. Psychol.* 63, 427–452 (2012).
12. Gordon, P. C., Islam, A. T. & Wright, H. H. Rapid automatized naming (ran): effects of aging on a predictor of reading skill. *Aging, Neuropsychology, and Cognition* 28, 632–644 (2020).
13. Stiver, J. et al. The rapid naming test: development and initial validation in typically aging adults. *The Clinical Neuropsychologist* 36, 1822–1843 (2021).

14. Atkins, K. J. et al. The rapid naming test: neuroanatomical validity and clinical utility. *Alzheimer's & Dementia (Amsterdam, Netherlands)* 17, e70216 (2025).
15. Soble, J. R. et al. Slow and steady does not always win the race: investigating the effect of processing speed across five naming tests. *Arch. Clin. Neuropsychol.* 31, 976–982 (2016).
16. Payne, B. R., Gao, X., Noh, S. R., Anderson, C. J. & Stine-Morrow, E. A. L. The effects of print exposure on sentence processing and memory in older adults: evidence for efficiency and reserve. *Aging, Neuropsychology, and Cognition* 19, 122–149 (2012).
17. Jia, J. et al. The prevalence of dementia in urban and rural areas of china. *Alzheimer's & Dementia* 10, 1–9 (2013).
18. Robbins, R. N., Scott, T., Joska, J. A. & Gouse, H. Impact of urbanization on cognitive disorders. *Curr. Opin. Psychiatr.* 32, 210–217 (2019).
19. Chen, X. et al. Differences in rural and urban health information access and use. *The Journal of Rural Health* 35, 405–417 (2018).
20. Kornilov, S. A. et al. Language development in rural and urban russian-speaking children with and without developmental language disorder. *Learn. Individ. Differ.* 46, 45–53 (2016).
21. Cristia, A. et al. Combining observational and experimental approaches to the development of language and communication in rural samples: opportunities and challenges. *J. Child Lang.*, 1–23 (2023).
22. Steinberg, N. et al. Rural-urban differences in cognition: findings from the advanced cognitive training for independent and vital elderly trial. *J. Aging. Health.* 35, 107S-118S (2022).
23. Weden, M. M., Shih, R. A., Kabeto, M. U. & Langa, K. M. Secular trends in dementia and cognitive impairment of u.s. Rural and urban older adults. *Am. J. Prev. Med.* 54, 164–172 (2018).
24. Jones-Gotman, M. & Milner, B. Design fluency: the invention of nonsense drawings after focal cortical lesions. *Neuropsychologia* 15, 653–674 (1977).
25. Zhan, W., Guo, R. & Chen, Y. Ccl corpus: center for chinese linguistics pku corpus [database]. http://ccl.pku.edu.cn:8080/ccl_corpus (2003).
26. Huang, C. R. & Chen, K. J. Academia sinica balanced corpus of modern chinese (version 3.0) [database]. http://asbc.iis.sinica.edu.tw (1998).
27. National Bureau of Statistics of China. Households' Income and Consumption Expenditure in 2024. https://www.stats.gov.cn/english/PressRelease/202501/t20250124_1958443.html (2025).
28. Delis, D. C., Kaplan, E. & Kramer, J. H. *Delis-kaplan executive function system (d-kefs)* (The Psychological Corporation, 2001).
29. Folstein, M. F., Folstein, S. E. & Mchugh, P. R. “Mini-mental state”. *J. Psychiatr. Res.* 12, 189–198 (1975).
30. Li, Y. et al. Culture effects on the chinese version boston naming test performance and the normative data in the native chinese-speaking elders in mainland china. *Front. Neurol.* 13, 866261 (2022).

31. Levelt, W. J. M., Roelofs, A. & Meyer, A. S. A theory of lexical access in speech production. *Behav. Brain Sci.* 22, 1–75 (1999).
32. Rodd, J. M. et al. Learning new meanings for old words: effects of semantic relatedness. *Mem. Cognit.* 40, 1095–1108 (2012).
33. Wang, X., Wang, B. & Bi, Y. Early language exposure affects neural mechanisms of semantic representations. *Elife* 12, e81681 (2023).
34. Perret, C. & Bonin, P. Which variables should be controlled for to investigate picture naming in adults? A bayesian meta-analysis. *Behav. Res. Methods* 51, 2533–2545 (2018).
35. Hashimoto, N., Heuer, S. & Cho, C. C. What drives response time and accuracy in image naming? Moderators in the relationship between number of phonological neighbors and image naming performance. *Frontiers in Language Sciences* 4 (2025).
36. Alario, F. X. et al. Predictors of picture naming speed. *Behavior Research Methods, Instruments, & Computers* 36, 140–155 (2004).
37. Trudeau-Meisner, M., Johns, B. T. & Taler, V. Contextual diversity and picture naming: the role of aging and bilingualism. *Bilingualism: Language and Cognition*, 1–17 (2025).
38. Lowder, M. W. & Gordon, P. C. Print exposure modulates the effects of repetition priming during sentence reading. *Psychon. Bull. Rev.* 24, 1935–1942 (2017).
39. Kirk, N. W., Kempe, V., Scott-Brown, K. C., Philipp, A. & Declerck, M. Can monolinguals be like bilinguals? Evidence from dialect switching. *Cognition* 170, 164–178 (2018).
40. Ferré, P., Jarret, J., Brambati, S., Bellec, P. & Joanette, Y. Functional connectivity of successful picture-naming: age-specific organization and the effect of engaging in stimulating activities. *Front. Aging Neurosci.* 12, 535770 (2020).
41. Liu, Y., Lu, G., Liu, L., He, Y. & Gong, W. Cognitive reserve over the life course and risk of dementia: a systematic review and meta-analysis. *Front. Aging Neurosci.* 16, 1358992 (2024).
42. Fritsch, T. et al. Cognitive functioning in healthy aging: the role of reserve and lifestyle factors early in life. *The Gerontologist* 47, 307–322 (2007).
43. Resch, C. et al. Young children's performance on a design fluency task: longitudinal data on total number of designs, clustering and switching, and regression-based norms. *J. Clin. Exp. Neuropsychol.* 46, 1–17 (2024).
44. Meyer, O. L. et al. Neighborhood socioeconomic status and cognitive trajectories in a diverse longitudinal cohort. *Clin. Gerontol.* 41, 82–93 (2017).
45. Zhang, T., Lu, B. & Wang, X. Urban-rural disparity in cognitive performance among older chinese adults: explaining the changes from 2008 to 2018. *Front. Public Health* 10, 843608 (2022).
46. Wong, R. & Mansour, A. Diverging cognitive benefits from education between rural and urban middle-aged and older adults in the usa. *Bjpsych Open* 11, e88 (2025).
47. Gupta, S. et al. Neuropsychological performance in mainland china: the effect of urban/rural residence and self-reported daily academic skill use. *Journal of the International Neuropsychological*

Society: Jins 17, 163–173 (2011).

Figures

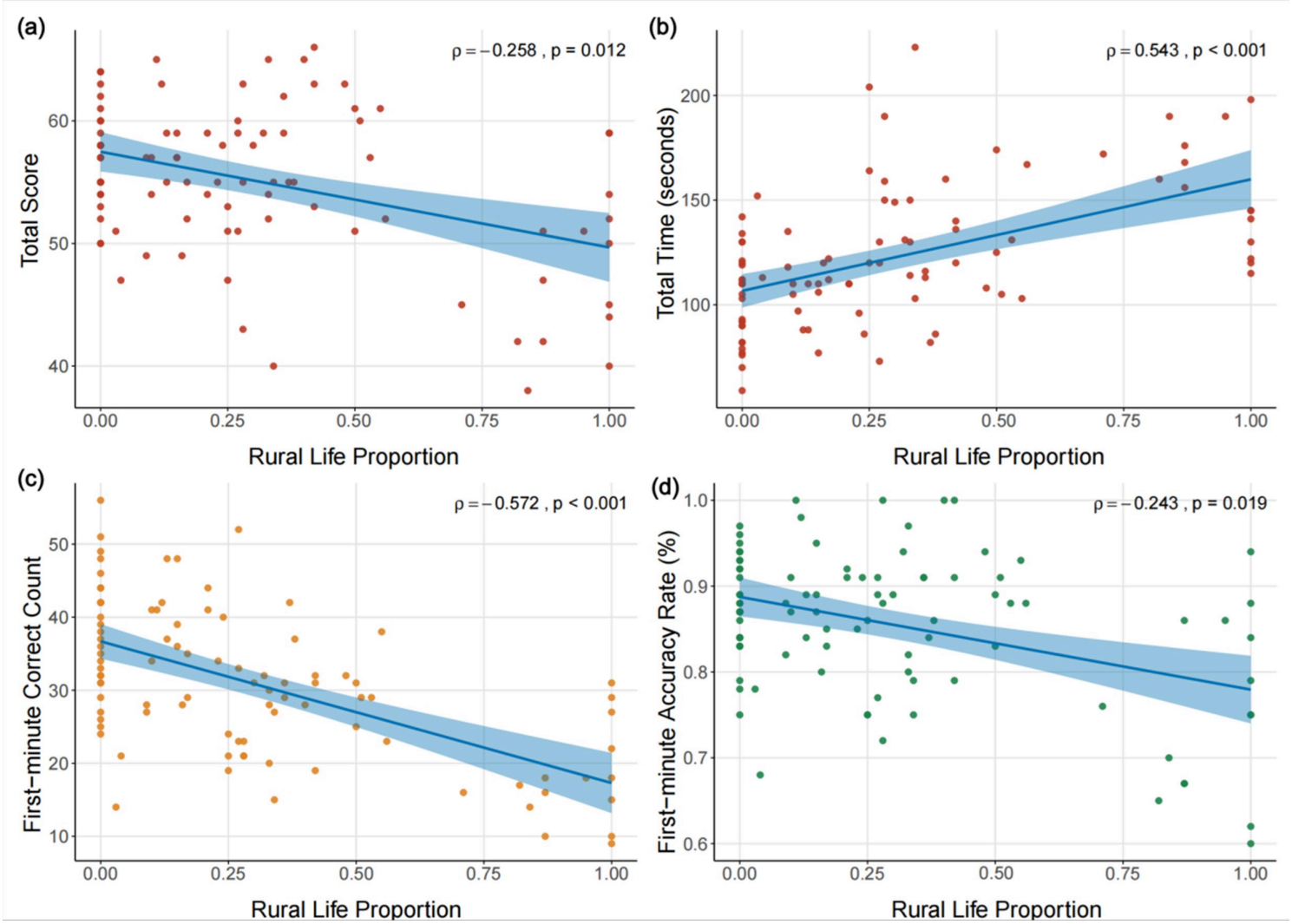


Figure 1

Associations between rural residence ratio and RNT-C outcome measures. Scatter plots illustrating the relayionships between rural residence ratio and (a) naming total score, (b) total completion time, (c) first-minute correct count, and (d) first-minute naming accuracy rate in 93 cognitively normal adults. Each point represents one participant. Spearman rank correlation coefficients (ρ) and corresponding p-values are displayed in each panel. Solid lines represent fitted regression lines, and shaded bands denote 95% confidence intervals.

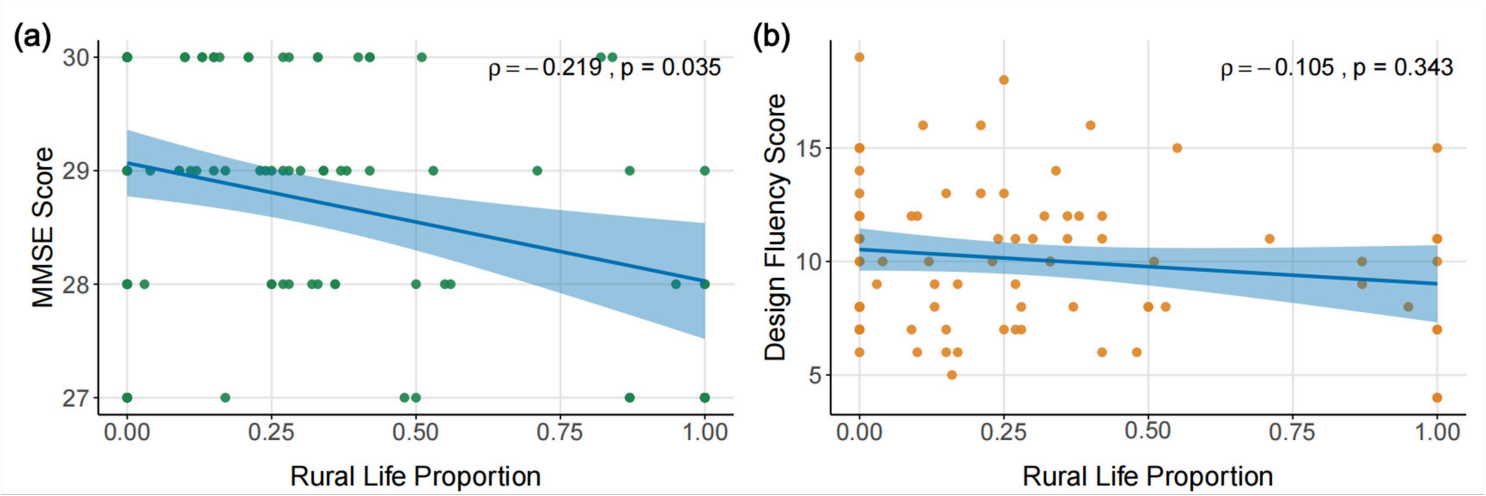
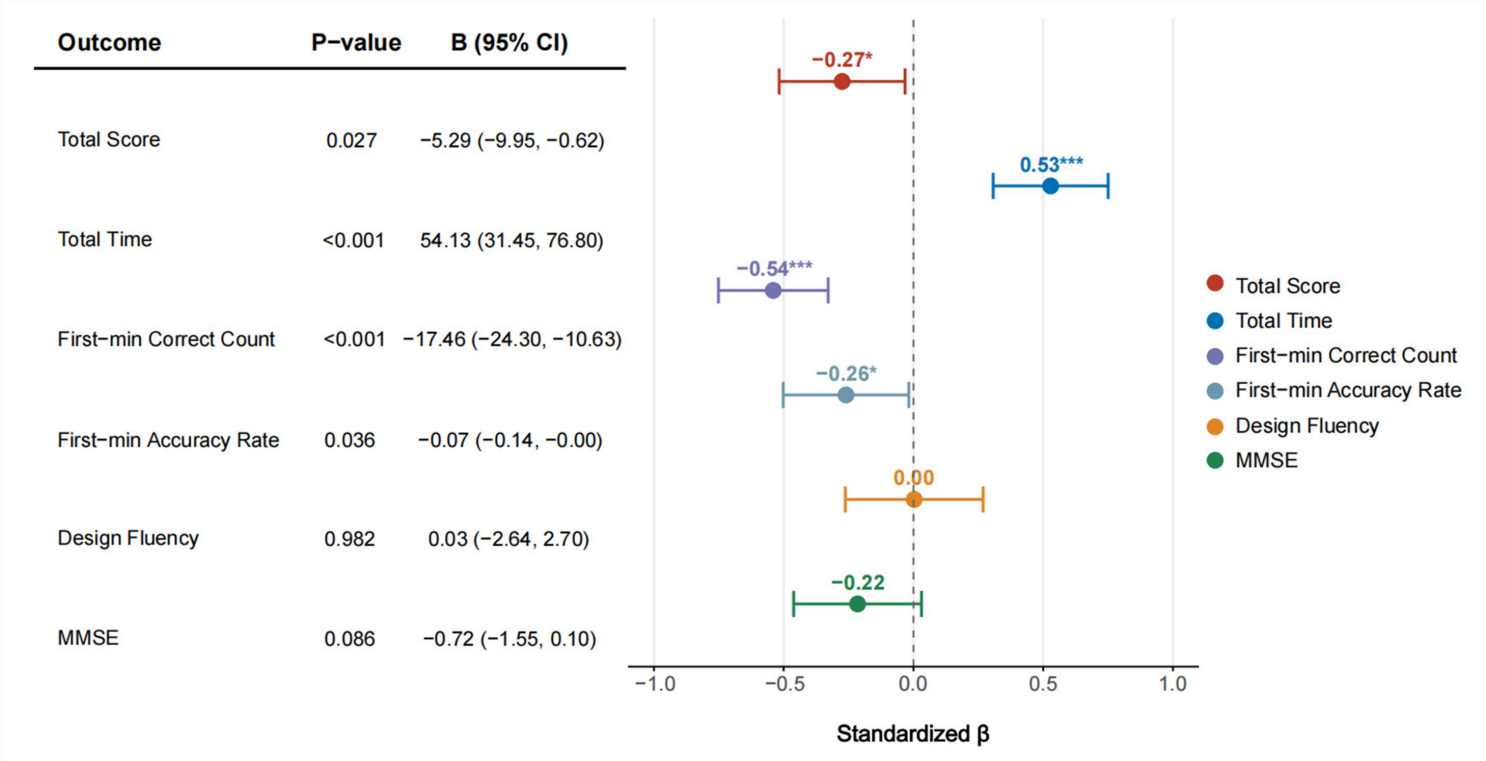


Figure 2

Associations between rural residence ratio and MMSE and Design Fluency scores. Scatter plots illustrating the associations between rural life proportion and (a) MMSE score and (b) Design Fluency score in 93 healthy controls. Each point represents an individual participant. Spearman's rank correlation coefficient (ρ) and the corresponding p-value are annotated in each panel Solid lines represent fitted regression lines, and shaded bands denote 95% confidence intervals.



Outcome	P−value	B (95% CI)
Total Score	0.027	−5.29 (−9.95, −0.62)
Total Time	<0.001	54.13 (31.45, 76.80)
First−min Correct Count	<0.001	−17.46 (−24.30, −10.63)
First−min Accuracy Rate	0.036	−0.07 (−0.14, −0.00)
Design Fluency	0.982	0.03 (−2.64, 2.70)
MMSE	0.086	−0.72 (−1.55, 0.10)

Figure 3

Summary of multivariable linear regression analyses of the independent effect of rural residence ratio on six cognitive outcomes. The left panel tabulates the unstandardised regression coefficient (B) with

95% confidence interval and p-value for rural residence ratio in each model. The right panel displays the corresponding standardised regression coefficients (β) as a forest plot; filled circles represent point estimates and horizontal bars represent 95% confidence intervals. Models predicting RNT-C outcomes and Design Fluency additionally adjusted for MMSE; the MMSE model excluded MMSE as a covariate. All models adjusted for sex, years of education, occupational category, and household income. Outcomes are colour-coded as indicated in the legend. *p < 0.05, ***p < 0.001.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- FigureS1.docx
- FigureS2.docx
- FigureS3.docx
- SupplTableS1noAge.docx
- SupplTableS2.docx