Postprint Study on Neuropsychological Changes in Post-Stroke Cognitive "Recoverers" Based on Dual Thresholds of the Montreal Cognitive Assessment

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Abstract

Background: Cognitive function in post-stroke patients is dynamic; however, research on post-stroke cognitive "recovery" is limited, and no studies have analyzed and compared the definitions of "recoverers" and their neuropsychological characteristics under different definitions. Objective: To investigate the neuropsychological characteristics of cognitive recoverers in stroke patients based on traditional definitions and a new dual-threshold MoCA definition. Methods: A total of 163 patients with first-episode acute ischemic stroke hospitalized in the Department of Neurology, Second Hospital of Hebei Medical University from December 2020 to February 2022 were enrolled as study subjects. At baseline, the Montreal Cognitive Assessment (MoCA) was used to evaluate cognitive function during the acute stroke phase. At 6-month follow-up post-stroke, cognitive function was reassessed, and comprehensive neuropsychological testing was completed, including the Digit Span Test (DST), Stroop Color-Word Test C (Stroop C), Chinese version of the Boston Naming Test (BNT), Verbal Fluency Test (VFT), Clock Drawing Test (CDT), and Auditory Verbal Learning Test (AVLT). On one hand, patients were divided into three groups (M1, M2, M3) based on MoCA dual thresholds (20/21, 25/26): MoCA score <21 as M1 group, MoCA score $ 26 as M3 group, and the remainder as M2 group. On the other hand, patients were categorized into Recoverer1 grou recoverer1 group (NR1 group), and R2 group and NR2 group based on two "recoverer" definitions. Results : After 6 months, patients were followed up, with 28 lost to follow—up, and 135 patients ultimately included. Themea points. At 6 months post-stroke, there were 40 patients in M1 group, 61 in M2 group, and 34 in M3 group. The MoCA scores at 6 months post-stroke, forward DST scores, backward DST scores, total DST scores, Stroop C time consumption, BNT Chinese version scores, VFT-animal, VFT-fruit, VFT-vegetable, CDT scores, AVLT-immediate scores, AVLT-short delay, AVLT-long delay,

and AVLT-recognition scores in M2 and M3 groups were higher than those in M1 group, while Stroop C error numbers were lower than those in M1 group (P<0.05). The MoCA scores at 6 months post-stroke, backward DST scores, total DST scores, CDT scores, AVLT-short delay, and AVLT-long delay in M3 group were higher than those in M2 group (P<0.05). Among the 135 patients, 120 with acute stroke phase MoCA score <26 were included as subjects for this analysis. Compared with acute stroke phase MoCA scores, 73 patients with $ $2-point improvement at follow-up were designated as R1 group, and 47 patients with <2-point improvement as NR1 group, yielding a recovery rate of 60.8% (73/120). The acute stroke phase MoCA scores in R1 group were lower than those in NR1 group, while follow-up MoCA scores were higher than those in NR1 group (P<0.05). Compared with acute stroke phase MoCA dual-threshold classification, 50 patients with increased scores at follow-up and crossing categories were designated as R2 group, and 70 patients without category crossing as NR2 group, yielding a recovery rate of 41.7% (50/120). The acute stroke phase MoCA scores, follow-up MoCA scores, backward DST scores, total DST scores, BNT Chinese version scores, VFT-vegetable, CDT scores, AVLT-immediate scores, AVLT-short delay, AVLT-long delay, and AVLT-recognition scores in R2 group were higher than those in NR1 group, while Stroop C time consumption, Stroop C error numbers, and VFT-animal were lower than those in NR1 group (P<0.05). Conclusion: Post-stroke patients exhibit varying degrees of impairment in attention, visuospatial function, and delayed recall. Under the traditional definition, there was minimal difference in neuropsychological test scores between recoverer and non-recoverer groups. However, under the new definition based on MoCA dual thresholds, recoverers demonstrated higher scores with greater clinical utility.

Full Text

Neuropsychological Changes of Cognitive Reverters after Stroke Based on the Montreal Cognitive Assessment (MoCA) with a Double Threshold

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Abstract

Background: Cognitive function is dynamic in post-stroke patients; however, there are limited studies on cognitive recovery after stroke. The definition of cog-

nitive reverters and their neuropsychological characteristics according to various definitions have not yet been investigated.

Objective: To investigate the neuropsychological characteristics of cognitive reverters after stroke based on both the traditional definition and a new definition using the Montreal Cognitive Assessment (MoCA) with a double threshold.

Methods: A total of 163 patients hospitalized for first-onset acute ischemic stroke were recruited from the Department of Neurology of the Second Hospital of Hebei Medical University from December 2020 to February 2022. All patients were assessed for cognitive function during the acute stroke period using the MoCA at baseline. Cognitive function was reassessed at the 6-month post-stroke follow-up, accompanied by detailed neuropsychological tests including the Digit Span Test (DST), Stroop Color and Word Test C (Stroop C), Chinese version of the Boston Naming Test (BNT), Verbal Fluency Test (VFT), Clock Drawing Test (CDT), and Auditory Verbal Learning Test (AVLT). Patients were divided into three groups based on MoCA double thresholds: M1 (MoCA scores <21), M2 (21 $\leq$ MoCA scores $\leq$ 25), and M3 (MoCA scores $\geq$ 26). Additionally, patients were classified into reverter and non-reverter groups according to two definitions of recovery.

Results: After 6 months, 28 patients were lost to follow-up, leaving 135 patients for analysis. The average MoCA score during the acute stroke period was (20.1$±$5.1). At 6 months post-stroke, there were 40 cases in M1, 61 in M2, and 34 in M3. The M2 and M3 groups showed significantly higher scores than M1 in MoCA, forward DST, reverse DST, total DST, Chinese BNT, CDT, Stroop C time consumption, VFT-animal, VFT-fruit, VFT-vegetable, AVLT-immediate, AVLT-short delay, AVLT-long delay, and AVLT-recognition (P<0.05). The M3 group also demonstrated higher scores than M2 in MoCA, reverse DST, total DST, CDT, AVLT-short delay, and AVLT-long delay (P<0.05).

Of the 135 patients, 120 had acute-phase MoCA scores <26 and were included in the reverter analysis. Using Definition 1 ($ $2-point improvement), 73 patients were classified as reverters (R1) and 47 as non-reverters (NR1), yielding a recovery rate of 60.8% (73/120). R1 patients had lower acute-phase MoCA scores but higher follow-up scores than NR1 (P<0.05). Using the double-threshold definition (improvement crossing categories), 50 patients were classified as reverters (R2) and 70 as non-reverters (NR2), with a recovery rate of 41.7% (50/120). R2 patients showed higher scores than NR2 across multiple domains including reverse DST, total DST, BNT, VFT-vegetable, CDT, and all AVLT measures, while showing lower Stroop C time consumption and error rates (P<0.05).

Conclusion: Post-stroke patients exhibit varying degrees of impairment in attention, visuospatial function, and delayed recall. While traditional definitions show minimal neuropsychological differences between reverters and non-reverters, the new double-threshold definition identifies reverters with significantly higher cognitive scores, offering greater clinical utility.

Keywords: Ischemic stroke; Cognition disorders; Neuropsychology; Mental

status and dementia tests; Recovery of function; Attention; Memory

Introduction

The incidence of stroke and dementia has been increasing in recent years, with stroke frequently accompanied by cognitive decline. Systematic reviews have reported a 38% prevalence of post-stroke cognitive impairment in the first year post-stroke and an 18.4% prevalence of post-stroke dementia. A 2-year follow-up study demonstrated that cognitive function in post-stroke patients is dynamic, with most cognitive improvement occurring within 6 months.

Previous research has extensively investigated the definition, classification, risk factors, and biomarkers of post-stroke cognitive impairment, but studies on predictors of cognitive "recovery" after stroke remain scarce. Current clinical predictions of post-stroke cognitive recovery are inaccurate. The Montreal Cognitive Assessment (MoCA) has been widely used both domestically and internationally due to its brevity and high predictive value for mild cognitive impairment; however, its optimal cutoff score remains controversial. In 2022, Dautzenberg et al. and Ramakers et al. proposed the MoCA double-threshold approach (20/21, 25/26), which addresses the challenge of maximizing specificity without sacrificing sensitivity.

Currently, two definitions exist for post-stroke cognitive "reverters": (1) patients with acute-phase MoCA scores <26 who show $ $2-point improvement at follow-up compared to baseline; and (2) patients with acute-phase MoCA scores <26 who achieve MoCA scores $ $26 at follow-up. This study employs the MoCA double-threshold to categorize patients into three groups: $M1 (MoCA < 21), M2 (21–25), and M3 (\geq 26)$. We also propose an improved Definition 3: patients with acute-phase $MoCA < 26$ who show categorical improvement at follow-up ($M1 \rightarrow M2, M2 \rightarrow M3, or M1 \rightarrow$ $M3). Through comprehensive neuropsychological assessment, we compare cognitive impairment characteristics across the three MoCA-defined groups and examine neuropsychological features of reverters versus non-reverters under both traditional and new double-threshold definitions.

Methods

Study Subjects

We recruited 163 patients admitted for first-onset acute ischemic stroke to the Department of Neurology at the Second Hospital of Hebei Medical University between December 2020 and February 2022. The study was approved by the hospital's Medical Ethics Committee (2019-R239), and all participants provided informed consent.

Inclusion criteria: (1) age $ $40 years; (2) confirmed first-onset acute ischemic stroke; (3) time from onset to admission $ $7 days; (4) clear consciousness capable of completing assessments; (5) informed consent and ability to cooperate with follow-up.

Exclusion criteria: (1) no formal education; (2) hearing impairment or poor cooperation preventing neuropsychological evaluation; (3) prior brain trauma or hemorrhagic cerebrovascular disease; (4) history of epilepsy, cognitive impairment, or psychiatric disorders; (5) severe systemic diseases such as pulmonary or cardiovascular conditions; (6) MRI contraindications.

Research Methods

During hospitalization (acute stroke period), we collected baseline demographic data (age, sex, education, medical history) and disease-related information [NIHSS score, new infarct location] and administered the MoCA assessment and brain MRI. At 6 months post-stroke, patients were followed up and underwent repeat cognitive evaluation with detailed neuropsychological testing.

Cognitive Assessment: The Beijing version of the MoCA evaluates 7 cognitive domains across 11 items: attention/concentration, executive function, memory, language, visuoconstructional skills, abstract thinking, calculation, and orientation. For education $ $12 years, a 1-point adjustment is added to the total score. MoCA total scores <26 indicate cognitive impairment.

Attention Function Assessment: The Digit Span Test (DST) includes forward and backward recall components to assess attention and working memory. Forward and backward scores range from 0-12 each, with the sum representing the total score.

Executive Function Assessment: The Stroop Color and Word Test C (Stroop C) requires patients to quickly and accurately name the ink color of 24 Chinese characters where the meaning differs from the color. After practice, timing begins (precise to 0.01 s) with manual recording of time and errors.

Language Function Assessment: The Chinese version of the Boston Naming Test (BNT) assesses language function by asking participants to spontaneously name 30 figures within 20 seconds each (maximum score 30). The Verbal Fluency Test (VFT) requires participants to retrieve words from long-term memory based on category cues, recording correct responses within 60 seconds for animals, fruits, and vegetables.

Visuospatial Function Assessment: The Clock Drawing Test (CDT) requires participants to draw a clock with numbers and hands pointing to 11:10, integrating spatial organization, numerical sequencing, and temporal concepts. Scoring uses the Rouleau 10-point method: clock face integrity (maximum 2 points), presence and ordering of numbers (maximum 4 points), and presence and placement of hands (maximum 4 points).

Episodic Memory Assessment: The Auditory Verbal Learning Test (AVLT) uses a list of 15 words ("drum, curtain, bell, coffee, school, father, moon, garden, hat, farmer, nose, turkey, color, house, river"). Participants undergo five learning trials, then recall after 3-5 minutes (short-delay) and 20 minutes (long-delay), followed by a 30-word recognition trial. Scores include immediate recall (sum of five trials), short-delay recall, long-delay recall, and recognition (correct minus incorrect responses).

Grouping Criteria: (1) Based on MoCA double thresholds: M1 (MoCA scores <21), M2 (21 $\leq$ MoCA scores $\leq$ 25), and M3 (MoCA scores $\geq$ 26). (2) Based on reverter definitions: Definition 1 classified patients with acute MoCA <26 as reverters (R1) if follow-up scores improved by $ 2*pointsversusnon* - *reverters*(*NR*1)*with* < 2 - *pointimprovement.Definition*2(*modified*)*classifiedpatientsasreverters*(*R*2)*iftheirfollow*-*upMoCAscoresincreasedandcrossedcategories*(*e.g.*, *M*1→*M*2, *M*2→*M*3, *M*1→$M3) versus non-reverters (NR2) who remained in the same category.

Statistical Analysis

Normally distributed continuous data are presented as mean ± standard deviation, compared between two groups using independent samples t-tests and among three groups using one-way ANOVA when homogeneity of variance was met. Non-normally distributed data are presented as median (interquartile range), compared between two groups using Mann-Whitney U tests and among three groups using Kruskal-Wallis H tests. Categorical data are presented as frequencies and compared using ^{2} tests. The significance level was set at α=0.05 (two-tailed).

Results

Baseline Characteristics

Of the 163 initially recruited patients, 28 were lost to follow-up, leaving 135 participants for analysis. The cohort included 107 males (79.3%) and 28 females (20.7%), with a mean age of (55.7$±8.7)*yearsandmedianeducationof*9*years.Sixty*-*ninepatients*(51.1±$5.1).

Patient Distribution at Acute Phase and 6 Months

During the acute phase, 66 patients were in M1, 54 in M2, and 15 in M3. At 6 months post-stroke, the distribution shifted to 40 in M1, 61 in M2, and 34 in M3.

Cognitive Domain Comparisons Among Three Groups at 6 Months

Significant differences were observed among M1, M2, and M3 groups in MoCA scores, forward DST, reverse DST, total DST, Stroop C time consumption, Stroop C errors, BNT scores, VFT-animal, VFT-fruit, VFT-vegetable, CDT scores, AVLT-immediate, AVLT-short delay, AVLT-long delay, and AVLT-recognition ($P<0.05$). Post-hoc comparisons revealed that M2 and M3 groups outperformed M1 in all these domains except Stroop C errors (which were lower in M2/M3). Additionally, M3 showed superior performance compared to M2 in MoCA scores, reverse DST, total DST, CDT scores, AVLT-short delay, and AVLT-long delay ($P<0.05$) .

Comparisons Between Reverter and Non-Reverter Groups

Among the 135 patients, 120 had acute-phase MoCA scores <26 and were included in the reverter analysis. Using Definition 1 ($ $2-point improvement), 73 patients were classified as reverters (R1) and 47 as non-reverters (NR1), yielding a recovery rate of 60.8% (73/120). R1 patients had lower acute-phase MoCA scores but higher follow-up scores than NR1 ($P<0.05$). However, no significant differences were found between R1 and NR1 in any specific cognitive domain scores ($P>0.05$) .

Using the double-threshold definition (categorical improvement), 50 patients were classified as reverters (R2) and 70 as non-reverters (NR2), with a recovery rate of 41.7% (50/120). R2 patients demonstrated significantly higher scores than NR2 in acute-phase MoCA, follow-up MoCA, reverse DST, total DST, BNT, VFT-vegetable, CDT, AVLT-immediate, AVLT-short delay, AVLT-long delay, and AVLT-recognition, while showing lower Stroop C time consumption and error rates ($P<0.05$). No significant differences were observed in forward DST or VFT-fruit scores between R2 and NR2 .

Discussion

Previous research on predictors of post-stroke cognitive recovery has yielded inconsistent or negative results. ABEN et al. found that only 5 of 33 candidate predictors showed predictive value for cognitive recovery after ischemic stroke in univariate analysis, highlighting the difficulty of predicting post-stroke cognitive recovery. Literature review reveals that two definitions of “reverters” are commonly used, with Definition 1 being more prevalent. However, both definitions have limitations. Definition 1 classifies many patients as “reverters” despite their MoCA scores remaining below 26 (i.e., still cognitively impaired), making the term misleading. Definition 2 requires patients to reach or exceed the international standard of MoCA $ $26, which may be overly stringent given that MoCA cutoffs are influenced by education, age, and cultural background, with significant variation across regions. WONG et al. demonstrated that traditional “one-size-fits-all” cutoffs lead to high misclassification rates, particularly

among stroke patients with different educational levels. Furthermore, no studies have compared neuropsychological characteristics across different reverter definitions.

This study applied the novel MoCA double-threshold concept to stroke patients and conducted comprehensive neuropsychological assessments. Our findings revealed significant differences among M1, M2, and M3 groups in attention (reverse DST and total score), visuospatial function, and delayed recall, while executive function, language, immediate recall, and recognition showed no differences between M2 and M3. This suggests that attention, visuospatial function, and delayed recall vary significantly across different overall cognitive levels in stroke patients, with DST, CDT, and AVLT being sensitive tools for distinguishing subtle differences in cognitive impairment severity.

We also improved upon Definition 2 by proposing Definition 3 based on the MoCA double-threshold: patients with acute-phase MoCA <26 who show categorical improvement at follow-up (M1→M2, M2→M3, or M1→M3). Regardless of definition used, approximately half of stroke patients showed cognitive recovery, consistent with most previous studies. Detailed neuropsychological assessment revealed that R1 patients had worse acute-phase MoCA scores but better follow-up scores than NR1, yet showed no domain-specific differences at follow-up. In contrast, R2 and NR2 differed significantly in both overall cognitive function and specific domains (attention, executive function, language, visuospatial, episodic memory) at follow-up, with R2 showing consistently higher scores. This indicates that under traditional definitions, differences between reverters and non-reverters are minimal, whereas the double-threshold definition identifies reverters with substantially better cognitive performance, providing greater clinical predictive and practical value.

In summary, integrating the novel MoCA double-threshold concept with comprehensive neuropsychological assessment, this study demonstrates that stroke patients show varying degrees of impairment in attention, visuospatial function, and delayed recall based on MoCA-defined groups. We innovatively propose a new reverter definition based on MoCA double-thresholds and demonstrate its superior clinical utility. These findings may aid in predicting recovery, investigating underlying mechanisms, and guiding cognitive rehabilitation for post-stroke patients. While our study employed comprehensive neuropsychological assessments, the time-intensive nature of these tests limited our sample size. Future large-scale longitudinal studies in Chinese populations are needed to better characterize post-stroke cognitive changes and recovery patterns.

References

[1] SEXTON E, MCLOUGHLIN A, WILLIAMS D J, et al. Systematic review and meta-analysis of the prevalence of cognitive impairment no dementia in the first year post-stroke[J]. Eur Stroke J, 2019, 4(2): 160-171. DOI:

10.1177/2396987318825484.

[2] CRAIG L, HOO Z L, YAN T Z, et al. Prevalence of dementia in ischaemic or mixed stroke populations: systematic review and meta-analysis[J]. J Neurol Neurosurg Psychiatry, 2022, 93(2): 180-187. DOI: 10.1136/jnnp-2020-325796.

[3] TURUNEN K E A, LAARI S P K, KAURANEN T V, et al. Domain-specific cognitive recovery after first-ever stroke: a 2-year follow-up[J]. J Int Neuropsychol Soc, 2018, 24(2): 117-127. DOI: 10.1017/S1355617717000728.

[4] HUANG Y Y, CHEN S D, LENG X Y, et al. Post-stroke cognitive impairment: epidemiology, risk factors, and management[J]. J Alzheimers Dis, 2022, 86(3): 983-999. DOI: 10.3233/JAD-215296.

[5] ROST N S, BRODTMANN A, PASE M P, et al. Post-stroke cognitive impairment and dementia[J]. Circ Res, 2022, 130(8): 1252-1271. DOI: 10.1161/CIRCRESAHA.122.319951.

[6] NIJSSE B, VISSER-MEILY J M, VAN MIERLO M L, et al. Temporal evolution of poststroke cognitive impairment using the Montreal cognitive assessment[J]. Stroke, 2017, 48(1): 98-104. DOI: 10.1161/STROKEAHA.116.014168.

[7] BANERJEE G, CHAN E, AMBLER G, et al. Effect of small-vessel disease on cognitive trajectory after atrial fibrillation-related ischaemic stroke or TIA[J]. J Neurol, 2019, 266(5): 1250-1259. DOI: 10.1007/s00415-019-09256-6.

[8] TANG W K, CHEN Y K, LU J Y, et al. Absence of cerebral microbleeds predicts reversion of vascular 'cognitive impairment no dementia' in stroke[J]. Int J Stroke, 2011, 6(6): 498-505. DOI: 10.1111/j.1747-4949.2011.00682.x.

[9] ABEN H P, BIESSELS G J, WEAVER N A, et al. Extent to which network hubs are affected by ischemic stroke predicts cognitive recovery[J]. Stroke, 2019, 50(10): 2768-2774. DOI: 10.1161/STROKEAHA.119.025637.

[10] ABEN H P, DE MUNTER L, REIJMER Y D, et al. Prediction of cognitive recovery after stroke: the value of diffusion-weighted imaging-based measures of brain connectivity[J]. Stroke, 2021, 52(6): 1983-1992. DOI: 10.1161/STROKEAHA.120.032033.

[11] LU J H, LI D, LI F, et al. Montreal cognitive assessment in detecting cognitive impairment in Chinese elderly individuals: a population-based study[J]. J Geriatr Psychiatry Neurol, 2011, 24(4): 184-190. DOI: 10.1177/0891988711422528.

[12] PINTO T C C, MACHADO L, BULGACOV T M, et al. Is the Montreal Cognitive Assessment (MoCA) screening superior to the Mini-Mental State Examination (MMSE) in the detection of mild cognitive impairment (MCI) and Alzheimer's Disease (AD) in the elderly?[J]. Int Psychogeriatr, 2019, 31(4): 491-504. DOI: 10.1017/S1041610218001370.

[13] WONG A, LAW L S, LIU W Y, et al. Montreal cognitive assessment: one cutoff never fits all[J]. Stroke, 2015, 46(12): 3547-3550. DOI:

10.1161/STROKEAHA.115.011226.

[14] SALVADORI E, COVA I, MELE F, et al. Prediction of post-stroke cognitive impairment by Montreal Cognitive Assessment (MoCA) performances in acute stroke: comparison of three normative datasets[J]. Aging Clin Exp Res, 2022, 34(8): 1855-1863. DOI: 10.1007/s40520-022-02133-9.

[15] DAUTZENBERG G M F C, LIJMER J G, BEEKMAN A T F. The Montreal Cognitive Assessment (MoCA) with a double threshold: improving the MoCA for triaging patients in need of a neuropsychological assessment[J]. Int Psychogeriatr, 2022, 34(6): 571-583. DOI: 10.1017/S1041610221000612.

[16] RAMAKERS I H G B, VERHEY F R J. Screening for neuropsychological assessment in the diagnostics of neurocognitive disorder[J]. Int Psychogeriatr, 2022, 34(6): 519-521. DOI: 10.1017/S104161022200031X.

[17] ZUO L J, DONG Y H, ZHU R Y, et al. Screening for cognitive impairment with the Montreal Cognitive Assessment in Chinese patients with acute mild stroke and transient ischaemic attack: a validation study[J]. BMJ Open, 2016, 6(7): e011310. DOI: 10.1136/bmjopen-2016-011310.

[18] BOWDEN S C, PETRAUSKAS V M, BARDENHAGEN F J, et al. Exploring the dimensionality of digit span[J]. Assessment, 2013, 20(2): 188-198. DOI: 10.1177/1073191112457016.

[19] SCARPINA F, TAGINI S. The Stroop Color and Word Test[J]. Front Psychol, 2017, 8: 557. DOI: 10.3389/fpsyg.2017.00557.

[20] SAXTON J, RATCLIFF G, MUNRO C A, et al. Normative data on the Boston Naming test and two equivalent 30-item short forms[J]. Clin Neuropsychol, 2000, 14(4): 526-534. DOI: 10.1076/clin.14.4.526.7204.

[21] ZHAO Q H, GUO Q H, HONG Z. Clustering and switching during a semantic verbal fluency test contribute to differential diagnosis of cognitive impairment[J]. Neurosci Bull, 2013, 29(1): 75-82. DOI: 10.1007/s12264-013-1301-7.

[22] CAREW T G, LAMAR M, CLOUD B S, et al. Impairment in category fluency in ischemic vascular dementia[J]. Neuropsychology, 1997, 11(3): 400-406. DOI: 10.1037/0894-4105.11.3.400.

[23] ROULEAU I, SALMON D P, BUTTERS N, et al. Quantitative and qualitative analyses of clock drawings in Alzheimer's and Huntington's disease[J]. Brain Cogn, 1992, 18(1): 70-87. DOI: 10.1016/0278-2626(92)90112-y.

[24] STRICKER N H, CHRISTIANSON T J, LUNDT E S, et al. Mayo normative studies: regression-based normative data for the auditory verbal learning test for ages 30-91 years and the importance of adjusting for sex[J]. J Int Neuropsychol Soc, 2021, 27(3): 211-226. DOI: 10.1017/S1355617720000752.

Author Contributions

LIU Yue, LIU Qi, DONG Hui, and LIU Yaling conceived and designed the study. LIU Yue collected and organized data, performed statistical analysis, interpreted results, and drafted the manuscript. LIU Qi and DONG Hui revised the manuscript. LIU Yaling provided overall supervision and accountability for the work. All authors approved the final version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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Note: Figure translations are in progress. See original paper for figures.