Predictive Value of the MoCA-T for Early Detection of MCI and Dementia in Taiwanese Older Adults

Cheng-Yu Huang, Jia-Hsun Lo, Han-Pang Huang, Su-Ching Sung, Wen-Chyuan Chen, Hui-Fen Chiou and Bo-Tao Hong

***Abstract*—This study delves into the relationship among MoCA-T scores, age, education level, and subtest performance. In this research, moderate correlations between MoCA-T scores and both age and education level are illuminated, and regression equations that serve as predictive tools for MoCA-T scores are further developed. Also, the study stratifies subjects into three distinct subgroups based on their MoCA-T scores, and subtests are categorized according to their score distribution within these subgroups. The implications of this study extend to the proposal of a cognitive hierarchy of dementia model, which outlines the course of dementia. This model underscores the potential utility of cognitive assessments, particularly in the realms of memory and language performance, for early detection. Ultimately, this research offers insights into the intricate connections between individual backgrounds, cognitive capabilities, and dementia, which stands poised to serve as a guide for the timely diagnosis of dementia in its early stages.**

***Index Terms*—MoCA-T, dementia, MCI, cognitive hierarchy, early detection**

I. Introduction

Dementia has become a common neurodegenerative disease in modern society, imposing significant burdens on both individuals and society. As the global population ages, the incidence of dementia continues to rise, presenting a significant worldwide public health challenge. Consequently, the need for early screening and monitoring tools for dementia has become imperative, enabling the identification and intervention for individuals experiencing cognitive decline in its early stages. In recent years, the Montreal Cognitive Assessment (MoCA) has garnered increasing attention as a potent cognitive evaluation instrument. Originating from the work of Nasreddine et al. in 2005 [1], MoCA is designed to offer a more sensitive and precise screening approach in contrast to the traditional Mini-Mental State Examination (MMSE). It encompasses a broad spectrum of cognitive domains, including memory, attention, language, visuospatial abilities, and executive functions, facilitating a comprehensive assessment of an individual's cognitive status.

A multitude of research studies have underscored the practicality of MoCA as a valuable tool for dementia screening. For example, Hoops et al.'s investigation in 2009 [2] demonstrated that MoCA outperformed the Mini-Mental State Examination (MMSE) in effectively detecting cognitive decline in individuals afflicted with Parkinson's disease. Similarly, Dong et al. (2016) [3] reported that MoCA displayed superior sensitivity and specificity when predicting vascular cognitive impairment (VCI), surpassing the National Institute of Neurological Disease and Stroke-Canadian Stroke Network (NINDS-CSN) 5-minute protocol. Additionally, Larner (2012) [4] delved into MoCA's screening potential and concluded that MoCA exhibited greater sensitivity, albeit with reduced specificity, ultimately delivering superior diagnostic accuracy compared to MMSE. These findings underscore MoCA's promise as a potent screening instrument, poised to deliver precise evaluations across diverse dementia types and varying stages of the disease.

Nonetheless, MoCA does come with its set of limitations and points of contention. Numerous research endeavors have underscored that MoCA's performance can be influenced by one's educational and cultural background [5]. These studies have stressed the significance of adaptive thresholds, tailored to individual characteristics and backgrounds, to enhance the precision and applicability of MoCA [6]. This body of evidence underscores the necessity for continued validation to assess MoCA's suitability across diverse demographic groups.

To examine the feasibility of applying MoCA in Taiwan, Tsai et al. (2012) [7] validated the psychometric properties of the Taiwanese version of MoCA (MoCA-T) for assessing Mild Cognitive Impairment (MCI) and dementia in the elderly population. The results indicated that MoCA-T outperformed MMSE significantly in detecting MCI and mild to moderate Alzheimer's disease (AD) and effectively identified individuals with AD. Additionally, the study identified the optimal cutoff scores for distinguishing MCI patients from normal controls as 23/24, where scores of 24 and above were considered normal, and scores below 23 indicated MCI. Similarly, the optimal cutoff scores for distinguishing AD patients from normal controls were 21/22, with scores of 22 and above classified as normal and scores below 21 indicated AD. Armed with these threshold data and information, we can further explore the connections between MoCA-T, MCI, and dementia, as well as assess the feasibility of MoCA in early screening, monitoring, and predicting Mild Cognitive Impairment (MCI) and dementia. This will contribute to a comprehensive understanding of the potential utility of MoCA in clinical practice and public health, laying the foundation for further research and clinical implementation.

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II. Materials and Methods

A. Dataset

The dataset used in this study was collected from two communities in Taoyuan, comprising a total of 60 participants aged between 50 and 90 years who completed the MoCA-T under supervision. Due to the similarity in the participants' lifestyles and living environments, to some extent, it ensured that the MoCA scores obtained in this study did not exhibit cultural background differences and could reasonably reflect the performance of the elderly population in Taiwan. Detailed information about the participants (subjects), including gender, age, and educational level, is presented in TABLE I.

TABLE I
Data of Subjects

	Level	Count	Total	Proportion
Gender	*Male*	16	60	0.267
	Female	44	60	0.733
Age	*50 to 59*	1	60	0.017
	60 to 69	30	60	0.500
	70 to 79	17	60	0.283
	80 to 89	11	60	0.183
	90 to 99	1	60	0.017
Education	*0*	10	60	0.167
	6	22	60	0.367
	9	10	60	0.167
	12	15	60	0.250
	16	3	60	0.050

B. Subgroup Division

In this experiment, scores from the Taiwanese version of the Montreal Cognitive Assessment (MoCA-T) scale were used as the basis for categorizing participants into subgroups. The maximum score on the MoCA-T is generally 30 points, but an additional point is added for individuals with 12 years of education or less.

In the original MoCA scale, a score of 26 is considered the cutoff point for distinguishing between individuals with Mild Cognitive Impairment (MCI) and Alzheimer's Disease (AD) patients from normal elderly controls [1]. In our study, since we utilized the MoCA-T and conducted the research in Taiwan, we referred to Tsai's research [7] and defined two cutoff scores: 23/24 to distinguish MCI and 21/22 to distinguish dementia. Therefore, we categorized the original participants into three subgroups: Normal Control (NC), Mild Cognitive Impairment (MCI), and Suspected Dementia (SD), as shown in Table II.

TABLE II
Data of Subgroups

MoCA-T Score	$0 \leq x \leq 21$	$22 \leq x \leq 23$	$x \geq 24$
Subgroup	Suspected Dementia (SD)	Mild Cognitive Impairment (MCI)	Normal Control (NC)
Count	21	9	30

C. Subtest Division

MoCA-T is a simple cognitive function assessment test used for rapid screening of Mild Cognitive Impairment (MCI) cases. The scale comprises 13 different subtests covering various domains of cognitive function, including attention, executive function, memory, language abilities, visuospatial construction, abstract concepts, calculation, and orientation. In this experiment, to understand the correlation between scores of individual participants on different tests and the subgroups determined by MoCA-T scores, we quantified the ungraded tests in the scale by the number of correct answers. Test codes, corresponding cognitive functions, and total scores for each subtest are displayed in Table III. It's worth noting that the memory test T5 is not included in the MoCA-T total score.

TABLE III
MoCA-T's Information Sheets for Various Tests

Test Code	Test Name	Cognitive Domain	Scores
T1	Alternating Trial Making	Executive Functions	1
T2	Visuoconstructional Skills Test (Cube)	Visuoconstructional Skills	1
T3	Visuoconstructional Skills Test (Clock)	Visuoconstructional Skills	3
T4	Naming Test	Image Recognition Capabilities	3
T5	Memory Test	Memory	10
T6	Attention Test	Attention	2
T7	Alertness Test	Attention	1
T8	Computing Test	Calculations	3
T9	Sentence Repetition Test	Language	2
T10	Verbal Fluency Test	Language	1
T11	Abstraction Test	Conceptual Thinking	2
T12	Delayed Recall Test	Memory	5
T13	Orientation Test	Orientation	6

III. Results

After collecting data from 60 participants, we conducted various statistical analyses on their MoCA-T scores, while also introducing different variables to observe the performance of distinct subgroups.

A. Age and Educational Level

Fig. 1 and 2 depict the visual distributions of the three subgroups concerning age and educational level, respectively. Please note that we utilized years of education as a quantifiable measure of educational level. Hence, in Fig. 2, the "Education Level" on the Y-axis represents the number of years of education the participants received.

Observing Fig. 1, it can be noted that the average age distribution of the three subgroups, from highest to lowest, is SD, MCI, and NC. On the other hand, by examining Fig. 2, the average years of education distribution of the three subgroups, from highest to lowest, is NC, MCI, and SD. The distribution trends for both males and females in both figures are similar, implying that gender does not appear to be a significant influencing factor.

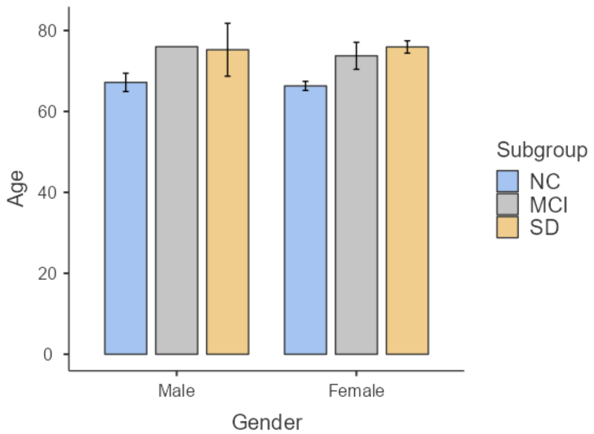

Fig. 1. Subject distribution in age in bar chart.

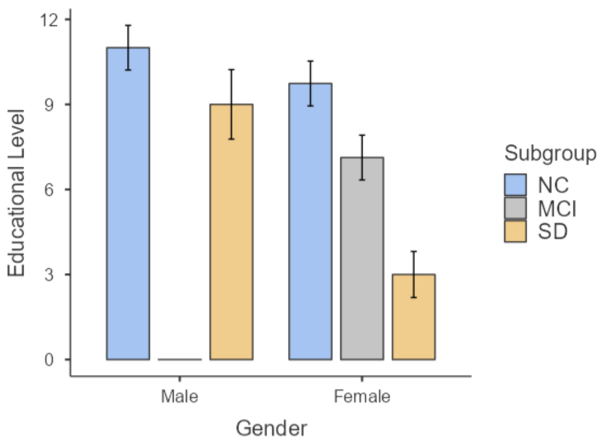

Fig. 2. Subject distribution in educational level in bar chart. (Note: The male MCI subgroup has a value of 0 because it consists of only one individual, resulting in a sampling error in representation due to the small sample size.)

To uncover the relationship between MoCA-T scores and age as well as educational level, we employed linear regression to illustrate the distribution trends among the data points. Fig. 3 and 4 respectively display the relationship between MoCA-T scores and age, as well as MoCA-T scores and educational level, among all participants. From the two regression lines in the figures, it is evident that age is negatively correlated with MoCA scores, while educational level is positively correlated with MoCA scores.

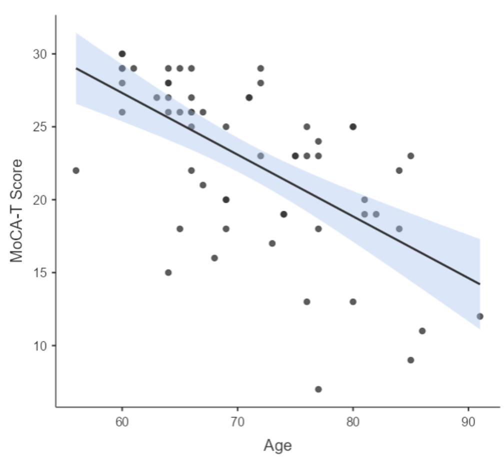

Fig. 3. Overall distribution of MoCA-T score versus age in scatter plot.

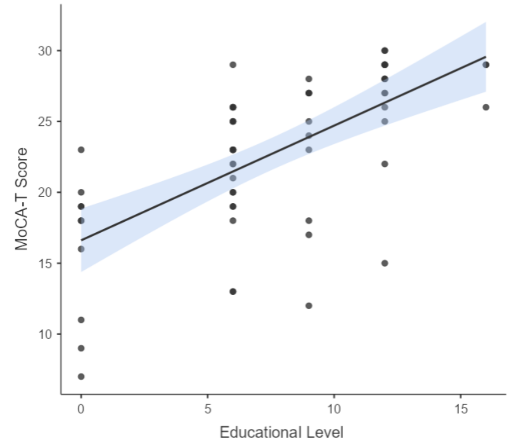

Fig. 4. Overall distribution of MoCA-T score versus educational level in scatter plot.

Additionally, Table IV and V present the fitting parameters for the relationship between MoCA-T scores and age, as well as MoCA-T scores and educational level, respectively. Meanwhile, Table VI and VII outline the regression coefficients for MoCA-T scores concerning age and educational level, including coefficients for intercepts and independent variables (age or years of education) among others. The coefficients in these four tables collectively aid in the computation of the statistical models employed in this study.

TABLE IV
FITTING PARAMETERS OF REGRESSION MODEL (MOCA-T SCORE VERSUS AGE)

							Overall Model Test			
Model	R	R²	Adjusted R²	AIC	BIC	RMSE	F	df1	df2	p
1	0.614	0.377	0.366	354	360	4.40	35.0	1	58	< .001

TABLE V
FITTING PARAMETERS OF REGRESSION MODEL (MOCA-T SCORE VERSUS EDUCATIONAL LEVEL)

							Overall Model Test			
Model	R	R²	Adjusted R²	AIC	BIC	RMSE	F	df1	df2	p
1	0.637	0.406	0.396	351	357	4.30	39.6	1	58	< .001

TABLE VI
REGRESSION COEFFICIENTS (MOCA-T SCORE VERSUS AGE)

			95% Confidence Interval					95% Confidence Interval	
Predictor	Estimate	SE	Lower	Upper	t	p	Stand. Estimate	Lower	Upper
Intercept	52.700	5.1048	42.482	62.919	10.32	< .001			
Age	−0.423	0.0715	−0.566	−0.280	−5.92	< .001	−0.614	−0.821	−0.406

TABLE VII
REGRESSION COEFFICIENTS (MOCA-T SCORE VERSUS EDUCATIONAL LEVEL)

			95% Confidence Interval					95% Confidence Interval	
Predictor	Estimate	SE	Lower	Upper	t	p	Stand. Estimate	Lower	Upper
Intercept	16.615	1.117	14.379	18.85	14.88	< .001			
Educational Level	0.809	0.129	0.552	1.07	6.29	< .001	0.637	0.434	0.840

With the statistical models in place, we can perform linear regression on the data and compute the regression equations. The linear regression equations for age and educational level can be separately derived from the intercepts and independent variables in Table VI and VII, as shown in (1) and (2). These two linear equations provide the possibility of predicting data, allowing us to infer an individual's performance on MoCA-T scores, or the distribution of age and educational level when new participants are evaluated in the future.

$$y = -0.423x + 52.700 \quad (1)$$

$$y = 0.809x + 16.615 \quad (2)$$

To further investigate the characteristics of the subgroups, we conducted linear regressions on them. Fig. 5 and 6 respectively depict the distribution of MoCA-T scores for the three subgroups based on age and educational level. In both of these figures, the regression lines and standard errors (shaded areas) for subgroup data are prominently displayed. Fig. 5 demonstrates that MoCA-T scores for the NC and SD subgroups tend to decline with increasing age. Fig. 6, on the other hand, shows a slight increase in MoCA scores when the educational levels of NC and SD are higher. In both figures, it can be observed that the standard error distribution is wider for the SD subgroup among the three subgroups, indicating greater sampling error, which suggests poorer representativeness of the samples in the SD subgroup for the overall data. On the other hand, it can be noted that both NC and SD follow the overall data trends, but MCI does not exhibit significant changes. This might be due to the smaller range of cutoff scores used during subgrouping (only 22 and 23), potentially creating a relatively fuzzy zone for the MCI subgroup that falls between NC and SD.

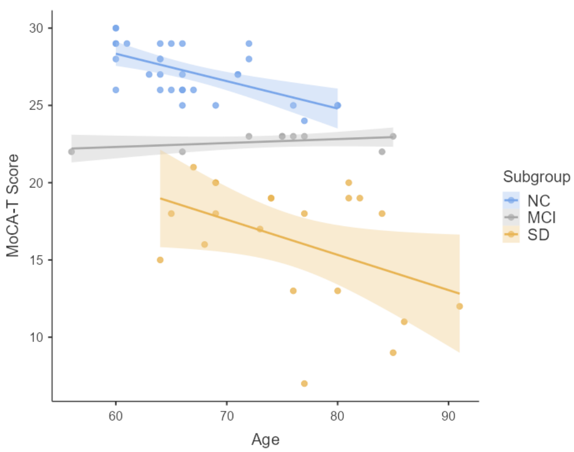

Fig. 5. Scatterplot of MoCA-T scores versus age in subgroups.

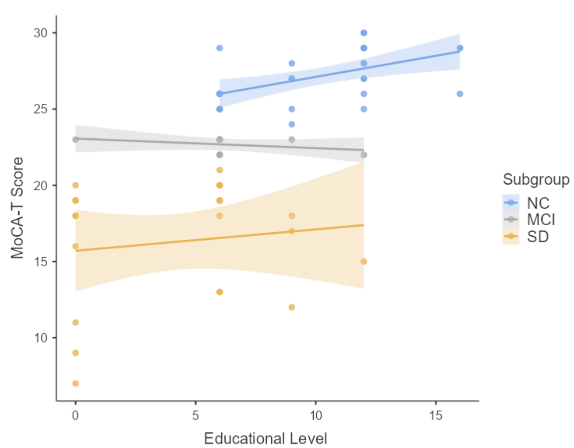

Fig. 6. Scatterplot of MoCA-T scores versus educational level in subgroups.

Since MoCA-T scores serve as not only an indicator of dementia but also a representation of participants' cognitive abilities, based on the results above, we can infer that cognitive ability is negatively correlated with age and positively correlated with educational level.

B. Cognitive Hierarchy of Dementia Model

The MoCA-T test consists of 13 subtests, each corresponding to different cognitive domains, as described in Section II. C. To uncover the relationship between cognitive domains and overall cognitive ability, this study devised a criterion to categorize the subtests into different stages of dementia, as shown in (3), (4), and (5), where μ_{NC}, μ_{MCI} and μ_{SD} represent the average scores for NC, MCI, and SD, respectively.

$$\mu_{NC} > \mu_{MCI} \fallingdotseq \mu_{SD} \tag{3}$$

$$\mu_{NC} > \mu_{MCI} > \mu_{SD} \tag{4}$$

$$\mu_{NC} \fallingdotseq \mu_{MCI} > \mu_{SD} \tag{5}$$

When a cognitive domain involves symptoms of dementia in early stage, it is considered as a high-class cognition. Such symptoms typically occur in MCI and SD, meeting the conditions outlined in (3). When a cognitive domain involves symptoms of dementia in intermediate stage, it is considered as a medium-class cognition. These symptoms typically occur in SD and partially in MCI, meeting the conditions outlined in (4). When a cognitive domain involves symptoms of dementia in late stage, it is considered as a low-class cognition. These symptoms only occur in SD, meeting the conditions outlined in (5).

The score distributions for the three subgroups are illustrated in Fig. 7 and 8. If (3) is satisfied, the distribution of MCI is closer to SD than NC. If (4) is satisfied, the distribution of MCI is neither close to SD nor NC. If (5) is satisfied, the distribution of MCI is closer to NC than SD. Observing the distribution trends in the score distribution plot is equivalent to computing the average scores for the three subgroups. Hence, according to the criteria mentioned above, the 13 subtests can be categorized into three symptomatic stages, as shown in Table VIII. Eventually, the subsets of T2, T5, and T9 can serve as indicators for early-stage dementia.

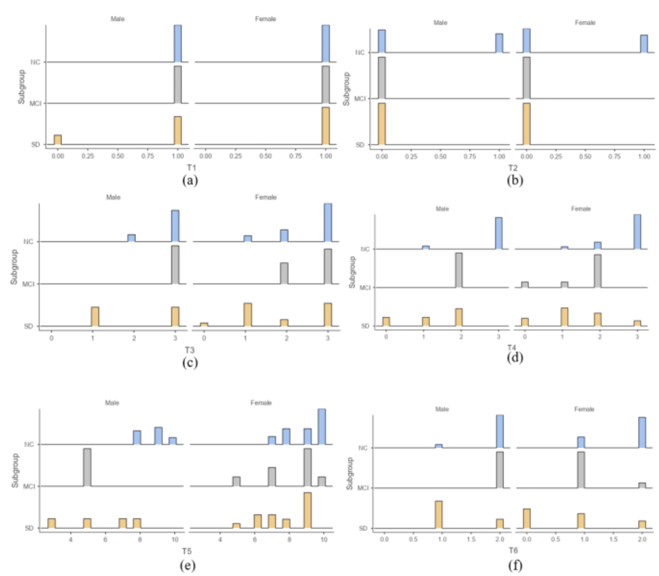

Fig. 7. The score distributions of NC, MCI, and SD in subtest T1 (a) to T6 (f).

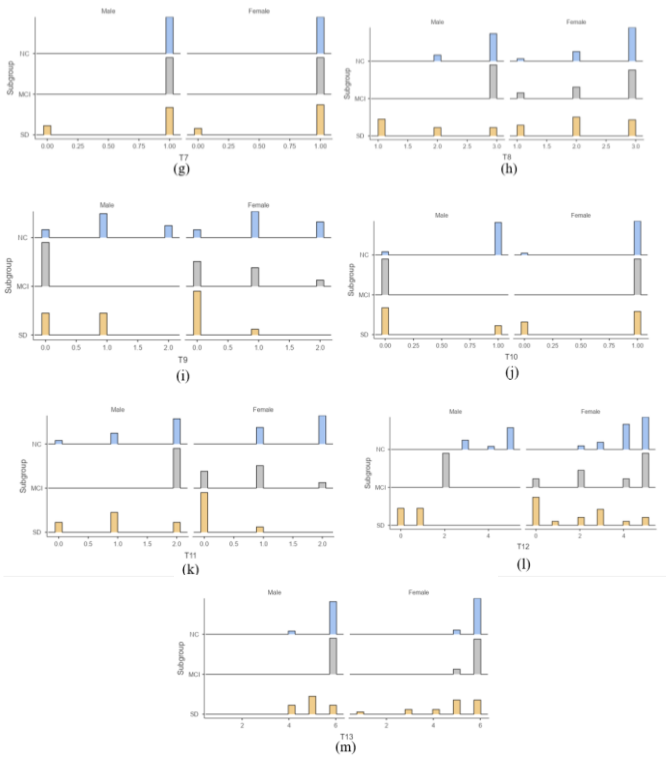

Fig. 8. The score distributions of NC, MCI, and SD in subtest T7 (g) to T13 (m).

TABLE VIII
SUBTEST RELATED TO DIFFERENT STAGES OF DEMENTIA

Dementia Stage	Declined Cognition	Subtests
Early stage	High-class	T2, T5, T9
Intermediate stage	Medium-class	T4, T6, T10, T11, T12
Late stage	Low-class	T1, T3, T7, T8, T13

Based on the aforementioned categorization, this study constructed a 3-level hierarchical structure of cognition to demonstrate the cognitive domains in MoCA-T subtests, as depicted in Fig. 9. Given the characteristic that dementia is accompanied by cognitive decline, it can be inferred that patients lose high-class cognitions in the early stage of dementia, often diagnosed as MCI. Patients lose medium-class cognitions in the intermediate stage of dementia, and in the late stage, they lose low-class cognitions.

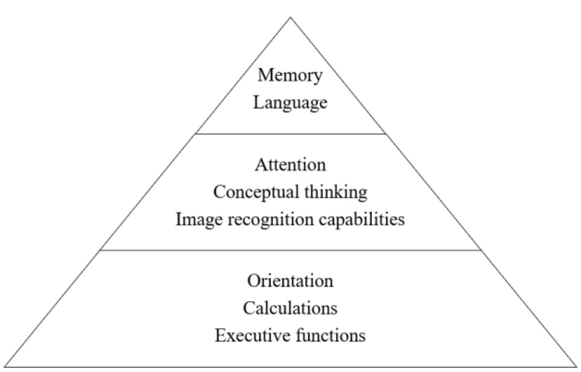

Fig. 9. Cognitive hierarchy of dementia model.

The cognitive hierarchy suggests that memory and language are in the advanced cognitive domain and can serve as predictive factors for early-stage dementia. It's worth noting that visuospatial construction skills are not included in the cognitive hierarchy because they encompass a range from low-class to high-class cognition, indicating that symptoms occur throughout the entire dementia process and are not suitable as predictive factors. This cognitive hierarchy structure of dementia describes the relationship between the cognitive domains present in MoCA-T and their corresponding stages of dementia, which can be further applied to future research on early predictive factors.

IV. CONCLUSION

In this study, we conducted statistical analyses that revealed a moderate negative correlation between MoCA-T scores and age, as well as a moderate positive correlation with education level. Through regression analysis, we derived linear regression equations for MoCA-T scores concerning age, education level, and scores from each test, which can be used to predict future participants' performance on MoCA-T. Additionally, this study inferred the relationship between stages of dementia and cognitive domains from the performance of three subgroups in the 13 subtests. Based on this, we proposed a cognitive hierarchy of dementia model to explain dementia symptoms at different stages. Therefore, by assessing these cognitive functions in conjunction with the aforementioned regression models and equations, early detection of dementia can potentially be achieved.

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