Testing four cognition bolt-on items to the EQ-5D in a general Chinese population

Meixia Liao[1]*, Hongyan Wu[2]*, Zhihao Yang[3], Yan Huang[4], Mathieu F. Janssen[5], Gouke Bonsel[6], Nan Luo[1]

* *Meixia Liao and Hongyan Wu are co-first authors and contributed equally.*

[1] Saw Swee Hock School of Public Health, National University of Singapore, Singapore, Singapore

[2] School of Medicine and Health Management, Guizhou Medical University, Guiyang, China

[3] Health Services Management Department, Guizhou Medical University, Guiyang, China

[4] Nanming Center for Disease Control and Prevention, Guiyang, China

[5] Section Medical Psychology and Psychotherapy, Department of Psychiatry, Erasmus MC, Rotterdam, The Netherlands

[6] EuroQol Research Foundation, Rotterdam, the Netherlands

Contact information for corresponding author:
Nan LUO, PhD
Saw Swee Hock School of Public Health
National University of Singapore
12 Science Drive 2, #10-01, Singapore 117549
E-mail: ephln@nus.edu.sg
Tel: (65) 6516 4966

Abstract

Objectives

This study aimed to evaluate the psychometric properties of four candidate cognition bolt-on items and their combinations to the EQ-5D-5L and EQ-5D-3L.

Methods

Four cognition bolt-on items (concentration, memory, calculation, and learning) were developed as separate questionnaire items, and were administered with the standard EQ-5D-5L to 640 individuals and with EQ-5D-3L to another 640 individuals in a general population survey in China. From 4 items, 11 compound items were constructed, and the 'worse level counts' rule was used to achieve a compound item score. Psychometric performance of the cognition bolt-ons was assessed in terms of informativity, convergent validity, explanatory power, and discriminatory power.

Results

The results for the three-level cognition bolt-on items to EQ-5D-3L were similar to those for the five-level cognition bolt-on items to EQ-5D-5L. The tested four cognition bolt-on items improved informativity, convergent validity, explanatory power and discriminatory power of EQ-5D-5L and EQ-5D-3L, with calculation and learning yielding better psychometric performance. The multi-domain bolt-on items that cover a range of subdomains of cognitive function demonstrated superior psychometric performance compared to single-domain bolt-on items, with those items covering calculation and learning resulting in better psychometric performance.

Conclusion

This study confirmed the validity of the tested cognition bolt-ons in a general Chinese population. It supported the use of a compound bolt-on item covering a range of cognitive functions such as ability to calculate and learn.

Introduction

The EQ-5D is a generic preference-based instrument measuring health related quality of life (HRQoL) [1]. Its descriptive system covers five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. It can be used to measure and compare HRQoL across different diseases or interventions. Nevertheless, there are some concerns about its adequacy to capture the HRQoL impact in some condition areas such as mental health, hearing and vision problems [2; 3]. Adding new items to the EQ-5D (i.e. bolt-ons) appears to be a solution as it could improve content validity and other measurement properties [4-6] while keeping the core EQ-5D intact.

Cognition impairment is known to have an impact on personality, mood, behaviour and global functioning [7]. Previous studies found that cognition is one of the most useful bolt-on dimensions for the EQ-5D [2; 8-10]. A number of studies have assessed the psychometric performance of various cognition bolt-ons for the EQ-5D-3L [11-14], EQ-5D-5L [15-17], and EQ-5D-Y-3L [18]. The impact of cognition bolt-ons on the valuation of EQ-5D health state was also studied [19; 20]. Findings from existing cognition bolt-on studies were mixed. Some studies concluded that cognition bolt-ons improve the measurement properties of EQ-5D such as content validity [17; 20], convergent validity [12; 16], explanatory power [11-13], and discriminatory power [17], while others reported minimal value of adding a cognition bolt-on to EQ-5D [14; 15].

Similar to the usual activities dimension of EQ-5D, cognition is a broad and heterogeneous health concept covering many aspects and levels of mental functions and processes, such as memory, attention, orientation, and language. Therefore, examples or subdomains should be provided in cognition bolt-ons to facilitate and standardize respondents' understanding of this health dimension. However, existing cognition bolt-ons use a variety of labels, including 'cognition' [16; 19], 'cognition, such as memory,

understanding, concentration, thinking' [15], 'cognition (memory, comprehension, concentration, thinking' [21; 22], 'cognition (such as memory, concentration) [12]', 'cognitive functioning (memory, concentration, coherence, IQ)' [14; 17; 20], 'cognitive functioning, such as remembering, concentrating' [11], and 'concentration' [13]. As the labels serve as a working definition for cognition, they may play a key role in the psychometric performance of cognition bolt-ons. However, no studies have investigated the effects of the individual cognition subdomains or their combinations on the psychometric properties of cognition bolt-ons. Without this knowledge, the best label definition for cognition bolt-on will remain elusive.

In view of this knowledge gap, we developed four cognition bolt-on items each targeting only one specific cognitive function, namely, concentration, memory, calculation, and learning, and evaluated the psychometric properties of the four bolt-ons, individually and in various combinations, in a general Chinese population.

Methods

Data collection

A cross-sectional survey was conducted in 6 areas in Guizhou province, China. Quota sampling was used to ensure the study sample was representative of the target general population in terms of age, sex, education level and residential area. Inclusion criteria were individuals who were: 1) residents living in rural or urban areas of Guizhou Province; 2) aged 16 and above; 3) able to converse in Mandarin; and 4) willing to take part in the study. A total of 22 trained interviewers (20 undergraduates and 2 postgraduates from Guizhou Medical University) recruited participants from conveniently selected community hospitals, public places such as parks and residential areas in the 6 areas. All interviews were one-on-one, face-to-face conducted in participants' homes, community hospitals, or parks. Each interview included questions

assessing demographic characteristics, Mini–Mental State Examination (MMSE), EQ-5D-5L or EQ-5D-3L, and four cognition bolt-on items with five response levels or three response levels.

Measures

MMSE is a widely used test for assessing cognitive impairment in clinical and research settings [23]. It includes questions that examine cognitive functions covering orientation to time and place (10 points), registration (3 points), attention and calculation (5 points), recall (3 points), language (2 points), repetition (1 points), and complex commands (6 points). A Chinese version of the MMSE was used in this study. It generates a maximum total score of 30 points. In this study, education-specific cut-offs of total MMSE score were used to diagnose mild cognitive impairment (MCI): ≤ 19 for illiterate individuals, ≤ 22 for those with elementary school education, and ≤ 26 for those with middle school education and above [24].

The EQ-5D questionnaires comprises a descriptive system and a visual analogue scale (EQ VAS) [1]. The descriptive system of the EQ-5D-5L and EQ-5D-3L questionnaires comprises the same five single-item dimensions including mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. The EQ-5D-5L has five response levels for each dimension (no problems, slight problems, moderate problems, severe problems, extreme problems/unable to), and the EQ-5D-3L has three response levels for each dimension (no problems, some problems, extreme problems/unable to). The EQ VAS assesses respondents' self-rated health on a vertical VAS ranging from 0 (worst imaginable health) to 100 (best imaginable health). For the descriptive system and EQ VAS, respondents are asked to evaluate their health on the day of survey.

Four cognition bolt-on items developed by the investigators were used in this study. Those included concentration, memory, calculation, and learning. Those cognition bolt-

on items were identified and selected based on literature review and consultation. Different from existing cognitive bolt-ons which cover multiple cognitive functions in a single item, the four cognition bolt-on items each targeted a different, specific cognitive function. Among the four functions, calculation was used to replace thinking, which was initially intended to be used. In a pilot study, we found that respondents had difficulty understanding the label 'thinking (clearly)' without a specific context. Instead, respondents could easily understand calculation, a different but related cognitive function. As calculation was deemed as an important cognitive function for day-to-day life that may not be predicted by basic cognitive functions such as concentration, we included calculation in this study. Each of the bolt-on items and its response options were phrased in the same way as the EQ-5D items. For example, the concentration item for EQ-5D-5L was phrased as 'I have no/slight/moderate/severe/extreme problems concentrating'. The four cognitive bolt-on items immediately followed the EQ-5D descriptive system and preceded the EQ VAS question in this survey.

Statistical analysis

We constructed 11 hypothetical cognitive bolt-on items using all the possible combinations of the 4 bolt-on items (6 covering 2 functions, 4 covering 3 functions, and 1 covering all 4 functions) and used the 'worse level counts' rule to determine how respondent would respond to them based on their responses to the 4 cognitive bolt-on items. For example, if an individual endorsed level-2 (slight problems) concentration and level-4 (severe problems) memory, calculation, and learning, we assumed the individual would report level-4 (severe problems) to the hypothetical item covering all 4 cognitive functions. We performed the following analyses for the 4 separate bolt-on items and the 11 hypothesized, compound items.

Informativity

We used Shannon diversity index (*H'*) and evenness index (*J'*) to assess informativity. The higher the Shannon's *H'* is, the more absolute information is captured by the specific items. The Shannon's *J'* captures specifically the relative informativity of the questionnaire or the 'evenness' of a distribution, regardless of the number of categories [25]. Therefore, the higher the *J'* is, the more relative information is captured by the specific items.

Convergent validity

For assessing convergent validity, we examined the correlation between the bolt-on items and the MMSE score using Spearman's rank correlation coefficient (ρ). For absolute values of Spearman's ρ, 0-0.40 is considered as weak, 0.41-0.70 as moderate, and >0.70 as strong [26]. We assumed convergent validity to be confirmed if there were moderate to strong correlation between the bolt-on items and the MMSE score.

Explanatory power

We used linear regression models to examine the extent to which the bolt-on items could explain the variance of the EQ VAS score in addition to the EQ-5D items. We first estimated a base model by regressing the EQ VAS over the five items of EQ-5D. The base model was subsequently extended with the bolt-on items, with each of them being added individually. We compared the size, direction, and statistical significance of the coefficients for each bolt-on item and associated change in the adjusted R-square. We hypothesized that the bolt-on items were significantly associated with the EQ VAS score and more variance of the EQ VAS score was explained by the bolt-on items compared to EQ-5D items alone.

Discriminatory power

We compared the ability of the bolt-ons to discriminate between individuals with differing levels of cognitive impairment defined by MMSE. We used both the F-statistic

derived from the ANOVA test, using the MMSE score as dependent variable, and the Area Under the Curve (AUC) in Receiver Operating Characteristic (ROC) analysis of the MCI status (presence/absence). In the ANOVA, the bolt-on item was treated as a grouping factor and cognitive impairment measured by MMSE score was treated as a continuous variable. In the ROC analysis of MCI, the bolt-on item score was treated as a continuous variable and MCI defined by MMSE was treated as a binary outcome. The bolt-on item that had the highest F-statistic and/or AUC value was considered to have the highest discriminatory power.

Validity and discriminatory power of the rescaled (bolt-on) EQ-5D level sum score

We assessed the potential added value of the bolt-ons by using a rescaled level sum score (LSS). The LSS was the sum of the level scores of all dimensions and the rescaled LSS was a 0-1 scale based on a linear transformation where the value for the all-best health state (e.g. 11111+1) was 0 and the all-worst health state (e.g. 55555+5) was 1. We used Spearman's ρ between the rescaled LSS and the MMSE score to assess the convergent validity. We examined the discriminatory power of the rescaled LSS using the F-statistic and AUC.

Results

A total of 640 participants were recruited and interviewed with EQ-5D-5L together with the five-level cognition bolt-on items, and another 640 participants completed EQ-5D-3L together with the three-level cognition bolt-on items. **Table 1** shows the characteristics of participants. The two groups of participants were similar in terms of their demographic characteristics. The mean age of the participants who completed the EQ-5D-5L was 46.16±21.07 years old. The majority of the participants were male (51.72%), residents of an urban area (50.00%), Han nationality (58.44%), married (62.97%), and completers of higher secondary or tertiary education (64.06%). The

mean MMSE score was 24.70±5.55, and 37.66% of the participants were considered with MCI.

Cognition bolt-on items to EQ-5D-5L

Table 2 shows the informativity, validity and discriminatory power of the cognition bolt-on items. For the five-level cognition bolt-on items to EQ-5D-5L, both *H'* and *J'* values generally increased with the number of cognitive functions the bolt-on items covered. The distributions of the level responses for cognition bolt-ons were shown in **Appendix Figure 1.** The correlation with MMSE ranged from -0.30 for the 'concentration' item to -0.69 for the 'memory / calculation / learning' and 'concentration / memory / calculation / learning' items. The highest F-statistic (159.43) value was observed for the 'calculation / learning' item, and the highest AUC (0.78) value was observed for two compound items both covering memory, calculation, and learning. More variance of the EQ VAS score was explained by the bolt-on items (adjusted R-square: 41% to 47%) compared to EQ-5D items alone (adjusted R-square: 40%), with those bolt-on items covering learning being more predictive.

Table 3 shows the validity and discriminatory power of the rescaled (bolt-on) EQ-5D LSS. The correlation of rescaled LSS with MMSE ranged from -0.49 (without bolt-on) to -0.66 (with four items covering calculation and learning). The highest F-statistic (152.31) value was observed for the 'memory/calculation/learning' item, and the highest AUC (0.77) value was observed for six items covering calculation.

Cognition bolt-on items to EQ-5D-3L

The results for the three-level cognition bolt-on items to EQ-5D-3L were similar to those for the five-level cognition bolt-on items to EQ-5D-5L. Both *H'* and *J'* values increased with the number of cognitive functions the bolt-on items covered, but the highest *H'* (0.98) and *J'* (0.90) values were observed for the 'calculation / learning' and

'concentration / calculation / learning' items. The correlation with MMSE ranged from -0.20 for the 'concentration' item to -0.59 for the 'calculation' item. The highest F-statistic (192.14) and AUC (0.71) values were observed for the 'calculation' item. More variance of the EQ VAS score was explained by the bolt-on items (adjusted R-square: 40% to 43%) compared to EQ-5D items alone (adjusted R-square: 39%), with those items covering learning being more predictive.

In LSS analysis, the correlation of rescaled LSS with MMSE ranged from -0.45 (with 'concentration' item) to -0.62 (with 'calculation' item). The highest F-statistic (130.02) and AUC (0.74) values was observed for the 'calculation' item.

Discussion

In this study, we tested four EQ-5D cognition bolt-on items, each targeting one specific subdomain of cognitive function, and evaluated the psychometric properties of the individual bolt-on items and their combinations in a general Chinese population sample. Our findings suggest that these single-domain cognition bolt-on items improved informativity, convergent validity, explanatory power and discriminatory power of EQ-5D-5L and EQ-5D-3L, with the calculation and learning items yielding the best psychometric performance. Moreover, we found that multi-domain bolt-on items that cover a range of cognitive functions had superior psychometric performance compared to single-domain bolt-on items, particularly those covering calculation and learning.

To the best of our knowledge, this is the first investigation of the psychometric properties of single-subdomain cognition bolt-ons to the EQ-5D. In our study, the subdomain of 'calculation' yielded the greatest increased discriminatory power among the four tested single-subdomain items. Ludwig et al. [18] identified 'school performance', 'concentration', 'memory' and 'learning ability' as the most relevant components of cognitive function in children and adolescents through literature review

and focus groups, and found that the best psychometric performance was achieved with 'memory'. The discrepancy between that study and our study might suggest that the psychometric performance of cognition bolt-ons differ in different populations, such as younger populations. This finding may have important implications for future bolt-on research. Currently, bolt-ons are developed as generic items for all the populations including both the general population and patient populations with different health condictiones. This strategy is preferred because, if it is successful, only a single cognition bolt-on is needed and comparability across populations is ensured. However, for broad health dimensions such as cognition, there may be no one version that can fit for purpose for all populations and contexts. As a result, different bolt-ons focusing on different aspects or subdomains of the health dimensions may be needed. Indeed, a cognition bolt-on covering concentration, memory, comprehension and thinking showed unsatisfactory construct validity in a Hungarian general population sample [22], but demonstrated increased construct validity in a Japanese elderly population sample [21].

The better psychometric performance of calculation and learning than memory and concentration might be explained by their more complex and multifaceted nature. Calculation and learning require the use of multiple basic functions, such as concentration, memory, and reasoning [27]. These higher levels of cognitive functions might be more suitable and discriminative for assessing populations in relatively healthier status such as the general population. This finding indicates that calculation and learning should be recognized as key components of cognition bolt-ons for the general population.

Furthermore, our study has provided evidence that cognition bolt-ons encompassing a range of subdomains of cognitive function may outperform single-subdomain items in

measurement. Previous cognition bolt-on studies used various labels to describe cognition bolt-on. Some studies used a simple label of 'cognition' [16; 19], while others listed specific subdomains of cognitive function, such as 'cognition, such as memory, understanding, concentration, thinking' [15], and 'cognitive functioning (memory, concentration, coherence, IQ)' [14; 17; 20]. However, none of those studies provided explanations for the choice of the included cognitive subdomains or investigated the psychometric performance of the selected subdomains. Our finding indicates that specifying the subdomains of cognition within the bolt-ons might facilitate a more effective and comprehensive assessment of cognitive function. This might also apply to other broad or multi-dimensional health concepts, such as sleep and relationships. For example, a relationship bolt-ons might benefit from providing subdomains such as personal relationships, social relationships, and social participation. It is of note that bolt-on studies should establish the validity of the chosen subdomains or examples to ensure that they are relevant and meaningful for the target population.

A limitation of our study is that our sample was conveniently sampled from a community-dwelling population. The results might be different if a specific patient group was sampled. Therefore, our findings might be limited to general population measurement. Future research could explore the psychometric properties of different cognition bolt-on descriptors to EQ-5D in a range of patient populations. Furthermore, it should be noted that the study was conducted solely in China and therefore our findings might not be generalizable to other countries or cultures. Additional research is needed to validate these findings in other countries. Lastly, the multi-domain cognition bolt-ons were hypothetical and tested as different combinations of the 4 single-subdomain bolt-ons and by assuming the 'worse level counts' rule for responses to those hypothetical bolt-ons. Therefore, results regarding the multi-domian cognition

bolt-ons should be interpreted with caution.

Conclusion

This study confirmed the value of a set of four cognition bolt-ons for general population health surveys using EQ-5D. It also provided evidence supporting the use of bolt-ons covering a range of cognitive functions including executive functions such as ability to calculate and learn in general population health surveys.

References

1. Devlin, N. J., & Brooks, R.: EQ-5D and the EuroQol group: past, present and future. Applied health economics and health policy. 15, 127-137 (2017).
2. Finch, A. P., Brazier, J. E., Mukuria, C., & Bjorner, J. B.: An exploratory study on using principal-component analysis and confirmatory factor analysis to identify bolt-on dimensions: the EQ-5D case study. Value in Health. 20(10), 1362-1375 (2017).
3. Finch, A. P., Brazier, J. E., & Mukuria, C.: Selecting bolt-on dimensions for the EQ-5D: examining their contribution to health-related quality of life. Value in Health. 22(1), 50-61 (2019).
4. Wang, P., Chong, S.-L., Tan, R. L.-Y., & Luo, N.: A hearing bolt-on item increased the measurement properties of the EQ-5D-5L in a community-based hearing loss screening program. The European Journal of Health Economics. 24(3), 393-398 (2023).
5. Luo, N., Wang, X., Ang, M., Finkelstein, E. A., Aung, T., Wong, T.-Y., & Lamoureux, E.: A vision "bolt-on" item could increase the discriminatory power of the EQ-5D index score. Value in Health. 18(8), 1037-1042 (2015).
6. Gandhi, M., Ang, M., Teo, K., Wong, C. W., Wei, Y. C.-H., Tan, R. L.-Y., Janssen, M. F., & Luo, N.: A vision 'bolt-on'increases the responsiveness of EQ-5D: preliminary evidence from a study of cataract surgery. The European Journal of Health Economics. 21, 501-511 (2020).
7. Pan, C.-W., Wang, X., Ma, Q., Sun, H.-P., Xu, Y., & Wang, P.: Cognitive dysfunction and health-related quality of life among older Chinese. Scientific reports. 5(1), 17301 (2015).
8. Efthymiadou, O., Mossman, J., & Kanavos, P.: Health related quality of life aspects not captured by EQ-5D-5L: results from an international survey of patients. Health Policy. 123(2), 159-165 (2019).
9. Shah, K., Mulhern, B., Longworth, L., & Janssen, B.: Important aspects of health not captured by EQ-5D: Views of the UK general public. Office of Health Economics (2016).
10. Geraerds, A. J., Bonsel, G. J., Janssen, M. F., Finch, A. P., Polinder, S., & Haagsma, J. A.: Methods used to identify, test, and assess impact on preferences of bolt-ons: A systematic review. Value in Health. 24(6), 901-916 (2021).
11. Ophuis, R. H., Janssen, M. F., Bonsel, G. J., Panneman, M. J., Polinder, S., & Haagsma, J. A.: Health-related quality of life in injury patients: the added value of extending the EQ-5D-3L with a cognitive dimension. Quality of life research. 28, 1941-1949 (2019).
12. Geraerds, A. J., Bonsel, G. J., Janssen, M. F., de Jongh, M., Spronk, I., Polinder, S., & Haagsma, J. A.: The added value of the EQ-5D with a cognition dimension in injury patients with and without traumatic brain injury. Quality of Life Research. 28, 1931-1939 (2019).
13. Jelsma, J., & Maart, S.: Should additional domains be added to the EQ-5D health-related quality of life instrument for community-based studies? An analytical descriptive study. Population Health Metrics. 13(1), 1-11 (2015).
14. Wolfs, C. A., Dirksen, C. D., Kessels, A., Willems, D., Verhey, F. R., & Severens, J. L.: Performance of the EQ-5D and the EQ-5D+ C in elderly patients with cognitive impairments. Health and quality of life outcomes. 5(1), 1-10 (2007).
15. Geraerds, A. J., Polinder, S., Spronk, I., Olde Loohuis, A. G., de Groot, A., Bronner, M. B., & Haagsma, J. A.: Sensitivity of the EQ-5D-5L for fatigue and cognitive problems and their added value in Q-fever patients. Quality of Life Research. 31(7),

2083-2092 (2022).
16. Geraerds, A. J., Bonsel, G. J., Polinder, S., Panneman, M. J., Janssen, M. F., & Haagsma, J. A.: Does the EQ-5D-5L benefit from extension with a cognitive domain: Testing a multi-criteria psychometric strategy in trauma patients. Quality of Life Research. 29, 2541-2551 (2020).
17. de Graaf, J. A., Kuijpers, M. M., Visser-Meily, J. M., Kappelle, L. J., & Post, M. W.: Validity of an enhanced EQ-5D-5L measure with an added cognitive dimension in patients with stroke. Clinical Rehabilitation. 34(4), 545-550 (2020).
18. Ludwig, K., Surmann, B., Räcker, E., & Greiner, W.: Developing and testing a cognitive bolt-on for the EQ-5D-Y (Youth). Quality of Life Research. 31(1), 215-229 (2022).
19. Finch, A. P., Brazier, J., & Mukuria, C.: Selecting bolt-on dimensions for the EQ-5D: testing the impact of hearing, sleep, cognition, energy, and relationships on preferences using pairwise choices. Medical Decision Making. 41(1), 89-99 (2021).
20. Krabbe, P. F., Stouthard, M. E., Essink-Bot, M.-L., & Bonsel, G. J.: The effect of adding a cognitive dimension to the EuroQol multiattribute health-status classification system. Journal of clinical epidemiology. 52(4), 293-301 (1999).
21. Igarashi, A., Sakata, Y., Azuma-Kasai, M., Kamiyama, H., Kawaguchi, M., Tomita, K., Ishii, M., & Ikeda, M.: Linguistic and Psychometric Validation of the Cognition Bolt-On Version of the Japanese EQ-5D-5L for the Elderly. Journal of Alzheimer's Disease(Preprint), 1-12 (2023).
22. Rencz, F., & Janssen, M. F.: Testing the psychometric properties of 9 bolt-ons for the EQ-5D-5L in a general population sample. the 40th EuroQol Plenary Meeting (2023).
23. Folstein, M. F., Folstein, S. E., & McHugh, P. R.: "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. Journal of psychiatric research. 12(3), 189-198 (1975).
24. Zhang, Z., Hong, X., & Li, H.: The mini-mental state examination in the Chinese residents population aged 55 years and over in the urban and rural areas of Beijing. Chinese Journal of Neurology. 32, 149-153 (1999).
25. Janssen, M. F., Birnie, E., & Bonsel, G. J.: Evaluating the discriminatory power of EQ-5D, HUI2 and HUI3 in a US general population survey using Shannon's indices. Quality of life research. 16, 895-904 (2007).
26. Akoglu, H.: User's guide to correlation coefficients. Turkish journal of emergency medicine. 18(3), 91-93 (2018).
27. Harvey, P. D.: Domains of cognition and their assessment. Dialogues in clinical neuroscience (2019).

Table 1. The characteristics of participants.

	5L (n=640)	**3L (n=640)**
Age, mean(SD)	46.16±21.07	46.22±20.99
Sex, n (%)		
Male	331 (51.72)	326 (50.94)
Female	309 (48.28)	314 (49.06)
Residence, n (%)		
Rural	320 (50.00)	320 (50.00)
Urban	320 (50.00)	320 (50.00)
Ethnicity, n (%)		
Han	374 (58.44)	443 (69.22)
Minor	266 (41.56)	197 (30.78)
Marital status, n (%)		
Single	184 (28.75)	182 (28.44)
Married	403 (62.97)	395 (61.72)
Divorced	6 (0.94)	16 (2.50)
Widowed	47 (7.34)	47 (7.34)
Education, n (%)		
No formal education	86 (13.44)	86 (13.44)
Primary	144 (22.5)	137 (21.41)
Junior high	146 (22.81)	167 (26.09)
Senior high	119 (18.59)	124 (19.38)
University & above	145 (22.66)	126 (19.68)
Income level, n (%)		
＜2000 RMB/month	382 (59.69)	353 (55.16)
2000-5000 RMB/month	176 (27.5)	215 (33.59)
5001-10000 RMB/month	61 (9.53)	58 (9.06)
＞10000 RMB/month	21 (3.28)	14 (2.19)
MMSE, mean(SD)	24.70±5.55	24.90±4.82
MCI		
No	399 (62.34)	410 (64.06)
Yes	241 (37.66)	230 (35.94)
EQ VAS, mean(SD)	76.19±20.22	77.02±18.52

MCI, mild cognitive impairment; MMSE, Mini–Mental State Examination; SD, standard deviation; VAS, visual analogue scale.

Table 2. The informativity, validity and discriminatory power of the cognition bolt-on items.

	5L						
	H'	***J'***	**MMSE [a]**	**F-statistic**	**AUC (95%CI)**	**EQ VAS [b]**	
						Coefficients (95%CI)	**Adjusted R^2**
Mobility	0.71	0.44	-0.44	44.39	0.63 (0.59, 0.66)	-3.83 (-6.27, -1.39)	
Self-care	0.26	0.16	-0.29	21.91	0.54 (0.52, 0.57)	-5.17 (-9.41, -0.92)	
Usual activity	0.64	0.40	-0.41	39.91	0.62 (0.58, 0.65)	-6.30 (-8.95, -3.66)	0.40
Pain/discomfort	1.03	0.64	-0.44	47.86	0.66 (0.62, 0.70)	-5.61 (-7.30, -3.92)	
Anxiety/depression	0.79	0.49	-0.19	7.91	0.56 (0.53, 0.60)	-5.89 (-7.87, -3.92)	
Concentration	0.83	0.52	-0.30	23.52	0.60 (0.56, 0.63)	-4.25 (-6.25, -2.24)	0.41
Memory	1.22	0.76	-0.54	57.31	0.70 (0.66, 0.74)	-5.49 (-6.99, -3.99)	0.44
Calculation	1.24	0.77	-0.64	151.52	0.76 (0.72, 0.80)	-5.10 (-6.37, -3.83)	0.45
Learning	1.35	0.84	-0.62	120.11	0.74 (0.70, 0.78)	-5.56 (-6.76, -4.35)	**0.47**
Concentration/ Memory	1.24	0.77	-0.55	59.80	0.70 (0.66, 0.74)	-5.15 (-6.67, -3.63)	0.44
Concentration/ Calculation	1.30	0.81	-0.62	148.29	0.75 (0.71, 0.79)	-5.38 (-6.67, -4.09)	0.46
Concentration/ Learning	1.38	0.85	-0.62	118.36	0.74 (0.70, 0.78)	-5.77 (-6.98, -4.55)	**0.47**
Memory/ Calculation	1.38	0.86	-0.66	145.21	0.77 (0.74, 0.81)	-5.47 (-6.75, -4.19)	0.46
Memory/ Learning	1.41	0.88	-0.66	123.28	0.75 (0.72, 0.79)	**-5.94 (-7.19, -4.70)**	**0.47**
Calculation/ Learning	1.43	0.89	-0.67	**159.43**	0.77 (0.73, 0.81)	-5.25 (-6.42, -4.08)	0.46
Concentration/ Memory/ Calculation	1.39	0.86	-0.66	146.37	0.77 (0.73, 0.80)	-5.38 (-6.68, -4.09)	0.46
Concentration/ Memory/ Learning	1.42	0.88	-0.65	120.44	0.75 (0.71, 0.79)	-5.91 (-7.16, -4.66)	**0.47**
Concentration/ Calculation/ Learning	1.44	0.89	-0.66	156.34	0.77 (0.73, 0.80)	-5.41 (-6.59, -4.22)	**0.47**
Memory/ Calculation/ Learning	1.45	0.90	**-0.69**	155.66	**0.78 (0.74, 0.81)**	-5.49 (-6.70, -4.27)	0.46
Concentration/ Memory/ Calculation/ Learning	**1.46**	**0.91**	**-0.69**	153.81	**0.78 (0.74, 0.81)**	-5.53 (-6.74, -4.31)	0.46

Table 2. The informativity, validity and discriminatory power of the cognition bolt-on items (continued).

	3L						
	H'	***J'***	**MMSE [a]**	**F-statistic**	**AUC (95%CI)**	**EQ VAS [b]**	
						Coefficients (95%CI)	**Adjusted R^2**
Mobility	0.37	0.33	-0.32	72.41	0.57 (0.54, 0.59)	-6.84 (-10.97, -2.71)	
Self-care	0.12	0.11	-0.19	38.16	0.52 (0.51, 0.54)	-10.01 (-17.64, -2.38)	
Usual activity	0.34	0.31	-0.31	75.53	0.56 (0.53, 0.59)	-7.64 (-11.97, -3.32)	0.39
Pain/discomfort	0.62	0.56	-0.43	77.04	0.62 (0.59, 0.66)	-14.83 (-17.62, -12.05)	
Anxiety/depression	0.57	0.52	-0.23	16.28	0.60 (0.56, 0.63)	-8.68 (-11.35, -6.02)	
Concentration	0.49	0.44	-0.20	21.26	0.56 (0.53, 0.60)	-3.75 (-6.75, -0.74)	0.40
Memory	0.77	0.70	-0.45	73.85	0.68 (0.64, 0.72)	**-6.86 (-9.10, -4.62)**	**0.43**
Calculation	0.77	0.70	**-0.59**	**192.14**	**0.71 (0.67, 0.75)**	-5.73 (-7.92, -3.54)	0.42
Learning	0.97	0.88	-0.48	98.32	0.66 (0.62, 0.70)	-5.26 (-6.92, -3.59)	**0.43**
Concentration/ Memory	0.77	0.70	-0.43	64.66	0.67 (0.63, 0.71)	-6.34 (-8.59, -4.09)	0.42
Concentration/ Calculation	0.81	0.74	-0.53	149.07	0.68 (0.65, 0.72)	-5.18 (-7.32, -3.05)	0.41
Concentration/ Learning	0.97	0.89	-0.46	86.06	0.65 (0.61, 0.69)	-4.92 (-6.60, -3.23)	0.42
Memory/ Calculation	0.83	0.76	-0.52	118.16	0.69 (0.65, 0.73)	-5.54 (-7.68, -3.40)	0.42
Memory/ Learning	0.96	0.87	-0.45	74.30	0.65 (0.61, 0.69)	-5.66 (-7.43, -3.89)	**0.43**
Calculation/ Learning	**0.98**	**0.90**	-0.51	107.52	0.67 (0.63, 0.71)	-5.10 (-6.77, -3.42)	**0.43**
Concentration/ Memory/ Calculation	0.82	0.75	-0.50	107.99	0.68 (0.64, 0.71)	-5.23 (-7.39, -3.07)	0.41
Concentration/ Memory/ Learning	0.95	0.87	-0.44	71.31	0.65 (0.61, 0.69)	-5.52 (-7.31, -3.73)	**0.43**
Concentration/ Calculation/ Learning	**0.98**	**0.90**	-0.48	93.07	0.66 (0.62, 0.70)	-4.90 (-6.60, -3.20)	0.42
Memory/ Calculation/ Learning	0.96	0.87	-0.47	78.22	0.65 (0.62, 0.69)	-5.20 (-7.00, -3.41)	0.42
Concentration/ Memory/ Calculation/ Learning	0.95	0.87	-0.46	74.78	0.65 (0.61, 0.69)	-5.12 (-6.94, -3.31)	0.42

H', Shannon diversity index; *J'*, Shannon evenness index; MMSE, the Mini–Mental State Examination; VAS, visual analogue scale; AUC, Area Under the Curve in Receiver Operating Characteristic analysis.

[a] The correlation between items and MMSE are all statistically significant at p-value<0.001.

[b] A base model was first estimated by regressing the EQ-VAS on the five items of EQ-5D. The base model was repeatedly re-estimated by adding the bolt-on items, one item at each time.

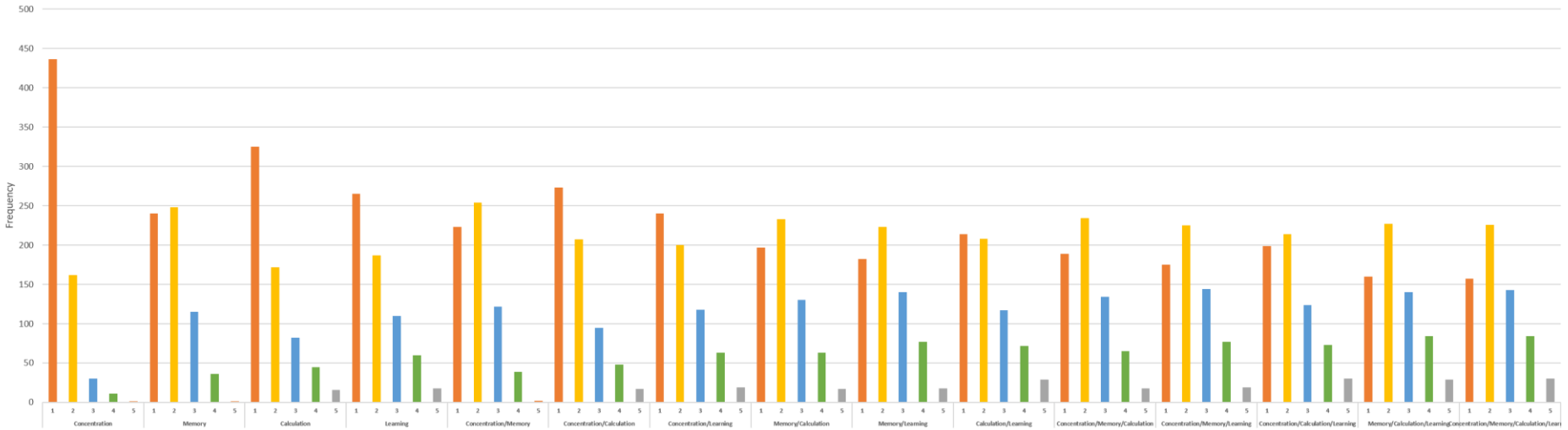
Each category's best-performing numbers are highlighted in bold.

Table 3. The validity and discriminatory power of the rescaled (bolt-on) EQ-5D level sum score.

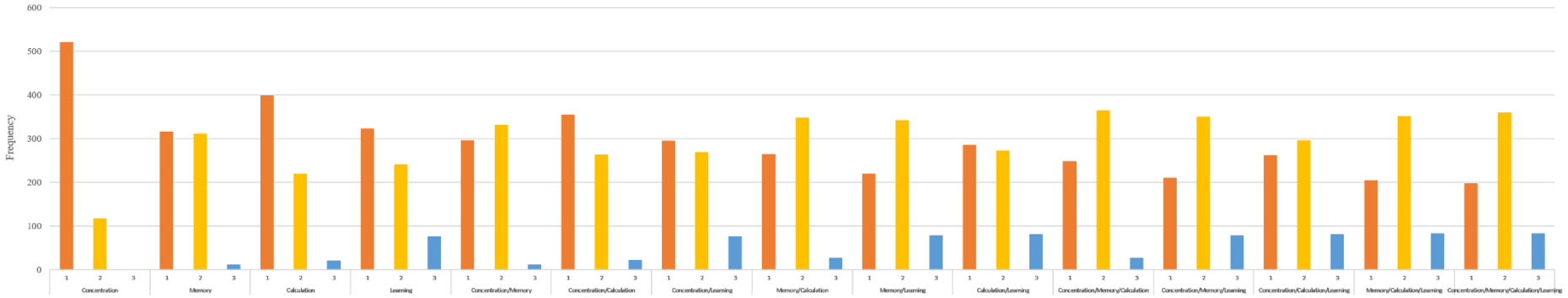
	5L			3L		
Rescaled LSS	**MMSE**	**F-statistic**	**AUC (95%CI)**	**MMSE**	**F-statistic**	**AUC (95%CI)**
EQ-5D	-0.49	85.47	0.69 (0.65, 0.73)	-0.46	77.24	0.68 (0.64, 0.72)
EQ-5D+Concentration	-0.51	88.42	0.70 (0.66, 0.74)	-0.45	78.69	0.67 (0.63, 0.72)
EQ-5D+Memory	-0.60	118.56	0.74 (0.70, 0.78)	-0.54	112.20	0.72 (0.68, 0.76)
EQ-5D+Calculation	-0.64	150.10	**0.77 (0.73, 0.80)**	**-0.62**	**130.02**	**0.74 (0.70, 0.78)**
EQ-5D+Learning	-0.64	138.23	0.75 (0.71, 0.79)	-0.59	107.52	0.72 (0.68, 0.76)
EQ-5D+Concentration/ Memory	-0.60	115.38	0.74 (0.70, 0.78)	-0.53	109.99	0.72 (0.68, 0.76)
EQ-5D+Concentration/ Calculation	-0.63	141.77	0.76 (0.72, 0.79)	-0.59	116.23	0.73 (0.69, 0.77)
EQ-5D+Concentration/ Learning	-0.64	135.02	0.75 (0.71, 0.79)	-0.58	103.41	0.71 (0.67, 0.75)
EQ-5D+Memory/ Calculation	-0.65	149.78	**0.77 (0.73, 0.80)**	-0.58	118.52	0.73 (0.69, 0.77)
EQ-5D+Memory/ Learning	-0.65	140.57	0.76 (0.72, 0.80)	-0.57	105.30	0.72 (0.68, 0.76)
EQ-5D+Calculation/ Learning	**-0.66**	151.57	**0.77 (0.73, 0.81)**	-0.61	113.74	0.73 (0.69, 0.77)
EQ-5D+Concentration/ Memory/ Calculation	-0.64	146.76	0.76 (0.73, 0.80)	-0.57	113.73	0.72 (0.69, 0.76)
EQ-5D+Concentration/ Memory/ Learning	-0.65	138.14	0.76 (0.72, 0.80)	-0.57	105.58	0.72 (0.68, 0.76)
EQ-5D+Concentration/ Calculation/ Learning	**-0.66**	148.37	**0.77 (0.73, 0.80)**	-0.59	106.42	0.72 (0.68, 0.76)
EQ-5D+Memory/ Calculation/ Learning	**-0.66**	**152.31**	**0.77 (0.73, 0.81)**	-0.58	105.94	0.72 (0.68, 0.76)
EQ-5D+Concentration/ Memory/ Calculation/ Learning	**-0.66**	150.05	**0.77 (0.73, 0.81)**	-0.57	105.50	0.72 (0.68, 0.76)

AUC, Area Under the Curve in Receiver Operating Characteristic analysis; LSS, level sum score; MMSE, the Mini–Mental State Examination; VAS, visual analogue scale.

Each category's best-performing numbers are highlighted in bold.



(a) Cognition bolt-on items to EQ-5D-5L



(b) Cognition bolt-on items to EQ-5D-3L

Appendix Figure 1. The distributions of the level responses for cognition bolt-ons.