Profiles of cognitive impairments in an older-age community sample: A latent class analysis

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Abstract

Objective: Person-centered studies that could describe the different patterns of cognitive impairments among the older people are lacking. To this end, the current study utilized a person-centered approach to examine the different profiles of cognitive impairment in an older-age Chinese community sample. Additionally, the current study also examined if functional impairments differ across the different profiles.

Method: A total of 220 older people (M_{age} =70.9 years) who were assessed to have an objective impairment in any of seven domains (immediate and delayed memory, attention, inhibition, verbal fluency, working memory and processing speed) were entered into a latent class analysis. Subsequently, functional impairment (both self-reported and clinician-rated) were then compared between the different profiles of cognitive impairments that had emerged from the analyses.

Results: A four-class solution was chosen based on fit statistics and interpretability. Three profiles were characterized by impairments in cognitive rigidity, memory and other executive functions, and the fourth with impairments in both executive functions and memory. Furthermore, relative to the non-memory impaired groups, the memory impaired groups were significantly more likely to report a higher level of clinician-rated functional impairments even though these groups do not differ significantly in self-reported functional impairments

Conclusions: The observed cognitive impairments in the current sample can be classified into four distinct profiles along the lines of memory and/or executive functions impairment. The memory-impaired groups were significantly impaired relative to the non-memory-impaired groups, at least in terms of clinician-rated functional outcomes. These findings present some important implications

Keywords: aging; cognitive impairments; executive functions; memory, functional impairments

Public Significance Statements

Age-related cognitive impairments tend to occur in four distinct profiles – memory with executive functions impairments, memory impairments, cognitive rigidity related impairments and executive functions impairments.

The memory impaired individuals appears to be more functionally impaired as compared to their non-memory impaired counterparts.

These profiles of cognitive impairments may facilitate better early detection of the different types of dementia and better inform future interventions in optimizing clinical outcomes

Background

Perhaps in relation to the ever-increasing global prevalence of dementia (Prince et al., 2015), extensive research has been conducted on age-related cognitive impairment. Such research has spanned across several cognitive domains (e.g., memory (Craik & Rose, 2012) and executive functions (Yuan & Raz, 2014)). Most findings in these areas were derived from variable-centered studies. Such studies typically employ regression analyses, structural equation modeling or factor analyses to investigate individual cognitive variables in relation to outcomes like daily functioning (e.g., Montejo, Montenegro, Fernández, & Maestú (2012)) and affective symptoms (e.g., Philippot & Agrigoroaei (2016)). Although these studies are meaningful on their own, one may nevertheless find it difficult to relate their findings to the real world because age-related cognitive impairments do not typically present in isolated cognitive domains. It is usually the case that an afflicted individual may present impairments in a number of different domains. Given the many possible combinations of impairments across multiple domains, it is not surprising that age-related cognitive impairments tend to be very heterogeneous among the population (Petersen et al., 2014).

With the revisions made to the Mayo Clinic criteria for mild cognitive impairment (MCI; Petersen, 2004), the MCI concept became a useful tool to relate a profile of cognitive impairments to a person, via its amnestic/nonamnestic and single/multiple-domain categories. However, such classification may not adequately encapsulate the different types of age-related cognitive impairments. For instance, Hanfelt et al. (2011) conducted a latent class analysis (LCA) on a large sample of participants with MCI and discovered six distinct profiles of cognitive impairment. The most common profile described individuals with executive function and language impairment. Evidently, this profile of cognitive impairment could not be adequately represented by the existing MCI categories; unlike memory, executive function was not a key feature of MCI's nosology.

Hanfelt et al.'s study is an example of a person-centered study. In person-centered research, the participants are classified into categories; each contains participants who are similar to each other and different from participants in the other categories. Given the heterogeneity in age-related cognitive impairments, person-center studies are very useful in delineating the different profiles or clusters of cognitive impairments among older people in a systematic manner. Although person-centered studies are not meant to serve as a substitute for variable-centered research, they nevertheless serve as an important complement. In the context of age-related cognitive impairments, they reveal much-needed information on the common patterns of cognitive impairments within a person.

To this end, the few person-centered studies in this area provide some interesting insights. However, they are subjected to certain significant limitations. In Hanfelt et al.'s study, cognitive impairments, along with neuropsychiatric features, were entered into the LCA analyses. Hence, the profiles that emerged were confounded with neuropsychiatric features. One could not help but wonder: if the neuropsychiatric features were not entered into the model, would the results be significantly different? One other study that used K-means clustering on a sample of clinically depressed older adults reported three profiles of cognitive impairment that corresponded to isolated memory impairment, memory and executive function impairment, as well as attention and memory impairment (Lockwood, Alexopoulos, Kakuma, & Van Gorp, 2000). However, these findings were subjected to two major limitations. Firstly, the use of a clinically depressed population may restrict generalizability to the general population. Secondly, this study also relied heavily on subjective self-report scales in assessing cognitive impairment, in contrast to the objective norms-based cognitive testing recommended in the assessment of MCI (Petersen et al., 2014).

Another study, which used latent profile analysis on a sample of MCI participants, reported three different profiles, namely the “least cognitive impaired,” “memory deficit” and “multiple deficit” (McGuinness, Barrett, McIlvenna, Passmore, & Shorter, 2015). In this study, the existence of a “least cognitively impaired” group, whose mean cognitive test z-scores were way above one standard deviation below the age and education norms, cast doubt on whether these subjects had genuinely met the criteria for MCI or to be considered cognitively impaired in the first place. Furthermore, the inclusion of these relatively unimpaired individuals into the model may also reduce the study’s ability to detect the different profiles of cognitive impairments. In addition to these concerns, these previous person-centered studies were carried out on western samples. The generalizability of these cognitive profiles to other populations such as the Chinese population in the present study remains unexplored. This is an important issue to be addressed especially since previous research have reported some cultural variability in the incidence of amnestic and nonamnestic MCI (Manly et al., 2008).

Given the limitations and scarcity of previous research in this area, there is a need to further investigate the different profiles of cognitive impairment among older people. To this end, the present study endeavored to examine the different profiles of cognitive impairment in a community sample of older people. Additionally, we aimed to compare the level of functional impairment between the different profiles of cognitive impairment so as to augment existing variable-centered research in this area (Montejo et al., 2012). In relation to the latter aim, we hypothesized that significant differences in functional impairment would appear across the different profiles of cognitive impairment.

Methods

Measures

Neuropsychological measures

Seven cognitive domains were assessed via locally adapted and normed measures for the purpose of the LCA. The Immediate Memory Index (IMI) and the Delayed Memory Index (DMI; a modification of the original General Memory Index (Tulsky, Chelune, & Price, 2004)) from the Wechsler Memory Scale (WMS-III; Wechsler, 1997), were used to assess participant's immediate and delayed memory, respectively. The IMI was derived from tests in which participants were asked to recall series of verbal (i.e., word pairs and information pertaining to a story) and visual stimuli (i.e., faces and family pictures) immediately after they were presented. In the DMI, participants were asked to recall these stimuli after an approximately 30-minute delay. Unlike the original General Memory Index in the WMS-III, the DMI does not include auditory recognition. Hence, the DMI is a "purer" measure of delayed recall and avoids some of the psychometric issues associated with the Auditory Recognition subtest (Tulsky et al., 2004). Next, the Digit Span subtests, which were also taken from the WMS-III, were used to index participant's working memory span. These tests require participants to immediately recall a series of numbers after they were read out, in the order that they were read out (forward) or in a reversed order (backward). To assess participants' processing speed, the Processing Speed Index (PSI) from the Wechsler Adult Intelligence Scale (WAIS-III; Wechsler, 1997; the newer WAIS-IV has yet to be adapted in the local context) was administered. This index was derived from participants' performance on the digit symbol coding and symbol search tasks that essentially tap on participants' ability to as quickly as possible, focus attention and scan, discriminate between, and sequentially order a series of visual stimuli. Participants' verbal fluency was assessed via the Verbal Fluency Test (VFT; Lee, Yuen, & Chan, 2002). In this test participants were first required to say aloud the names of as many different types of fruits and vegetables as possible within a minute and subsequently do the same for the names of animals in another one-minute test run. For the purpose of the present study, verbal fluency was operationalized as the total number of correct and unique (i.e., no credit was given for a word that was repeated) words. The Color Trails Tests (CTT; D'Elia, Satz, & Uchiyama, 1994) was used to assess sustained and divided attention. The CTT consists of two parts. In the first, participants were required to connect a series of numbers which were printed in colored circles in sequential order from 1 to 25. Subsequently in the second part, participants were required to alternate between choosing numbers in either pink or yellow circles while similarly connecting the numbers from 1 to 25. Participants' sustained and divided attention was operationalized as the completion times for both parts of the CTT. Finally, participants' cognitive inhibition was operationalized via the Stroop interference effect. This effect was measured using a local Chinese adaptation (Lee & Chan, 2000) of the Stroop Color-Word Test (Victoria version; Spreen and Strauss (1998)). The test stimuli consisted of three cards for the conditions of *dot*, *word*, and *color-word*. In each card, the items (appearing in blue, green, red and yellow colors) were presented in a 4 × 6 matrix. The *dot* condition was administered first; participants were instructed to name the color of the dots as quickly as possible. Next, participants named the colors of Chinese characters, first in the *word* condition and then in the *color-word* condition. Frequently used Chinese characters that were unrelated to color were presented in the *word* condition, while lexicon of color terms were presented in the *color-word* condition. The Stroop interference effect was computed as the difference in completion times between the *color-word* and *dot* conditions; a smaller Stroop interference effect (i.e., smaller differences) corresponded to better cognitive inhibition.

The raw scores of the DMI, IMI, PSI, Digit Span and Stroop interference were converted into age- and education-normed z-scores. As for the CTT and VFT, the norms of which were based on the raw scores of their respective subtests rather than their total scores, these subtests' raw scores were first converted into age- and education-normed z-scores.

Following this, composite scores for the CTT and VFT were computed for each participant by averaging his/her age- and education-normed z-scores from their respective subtests.

Functional impairments

The Clinical Dementia Rating (CDR; Hughes, Berg, Danziger, Coben, & Martin, 1982) and Cognitive Self-Report Questionnaire (CSRQ; Spina, Ruff, & Mahncke, 2006) were used to assess clinician-rated and self-reported functional impairment, respectively. CDR ratings for each participant were obtained via semi-structured interviews with a clinical psychologist and then integrating information from six different functional domains via the CDR assignment algorithm. In the current sample, participants were rated as CDR 0 or CDR 0.5, which corresponded, respectively, to the functional status of an unimpaired individual or one with very mild dementia. The CSRQ consisted of 25 items, each assessing on a five-point Likert scale, impairments in the social, cognitive and hearing domains over the past two weeks. Given that the hearing domain was irrelevant to the objectives of the current study, the hearing subscale was not used. Higher CSRQ scores relate to worse cognitive complaints.

Secondary measures

To obtain an overall cognitive status of the participants, a local adaptation (Wong et al., 2009) of the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) was administered. The MoCA consisted of a couple of brief tasks tapping on cognitive functions in the domains of visuo-executive, naming, attention, language, abstraction, delayed recall and orientation. Some examples of these tasks include serial subtraction, item naming and an abridged version of the digit span test. The MoCA was scored on a 30-point scale, and higher scores corresponded to better cognitive status.

The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) was used to assess the level of affective symptoms in our participants. The HADS consisted of two subscales – anxiety and depression, each comprising seven items. Each item was scored from 0 to 3. The HADS was validated in the local geriatrics context and had demonstrated excellent sensitivity and specificity in classifying mood and anxiety-disorder cases (Lam, Pan, Chan, Chan, & Munro, 1995). Higher scores on the HADS corresponded to greater mood disturbances.

Participants and procedures

Participants of the current study were recruited as part of a parent aging cohort study in Hong Kong (Yu, Lam, & Lee, 2016). This cohort study was approved by the Institutional Review Board of a university and hospital, and conducted in accordance with the ethical standards laid out in the 1964 Declaration of Helsinki and its later amendments. Recruitment procedures and criteria have been described in detail elsewhere (Leung et al., 2015). From the cohort of 480 participants, two participants aged 89 and above were excluded from this study because the neuropsychological norms were only appropriate up to the age of 88. Another four participants with CDR 1 ratings were excluded for the sake of uniformity (because everyone else had either CDR 0 or 0.5 ratings). From the remaining 474 participants, 220 who were assessed to have an objective cognitive impairment in any of the seven assessed cognitive domains were included in the present study. This final included sample consisted of 62 males and 158 females with a mean age of 70.9 years (range: 60 to 88; SD= 6.5) and an average of 8.4 years of education (SD= 4.6).

An “objective cognitive impairment” was defined in the current study as having test scores below one standard deviation of the age- and education-norms. This “one standard deviation” threshold for defining objective cognitive impairment had been frequently used in the assessment of MCI (Petersen et al., 2014), and had demonstrated excellent criterion validity in predicting conversion from MCI to dementia (Busse, Hensel, Gühne, Angermeyer, & Riedel-Heller, 2006). Nevertheless, it should be noted that not all of our participants have met the MCI criteria; some of them have not met the subjective cognitive complain criterion of MCI.

Statistical analysis

After obtaining participants' age- and education-normed z-scores from the seven different cognitive domains, z-scores $\leqslant$ -1 and z-scores > -1 were coded as 1s and 0s, respectively, to correspond to the presence of an impairment in the domain before entering into the LCA model. The LCA was carried out using the poLCA package in R (Linzer & Lewis, 2011) to fit one to six latent-class solutions to the data. The best solution was selected after examining fit indices such as the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample size adjusted BIC (aBIC), consistent Akaike Information Criterion (cAIC) and entropy values, and considering the solution's interpretability and parsimony. Next, participants were assigned to their most probable latent classes. Following which, group differences in demographics, psychiatric variables and functional impairment among the LCA-identified classes were analyzed via bootstrapped analysis of variance (ANOVA) and chi-square tests. Post-hoc tests were conducted with Tukey's tests and pair-wise chi-square tests where necessary. Bootstrapping was performed using the bias-corrected and accelerated approach with 5,000 bootstrap samples. These analyses, apart from the LCA, were carried out in the Statistical Package for the Social Sciences (SPSS version 22) software. Statistical significance was set at $p < .05$.

Results

Model selection

INSERT TABLE 1 AND FIGURE 1 HERE

The four-class solution was chosen after taking into account the fit statistics (see Table 1) as well as the parsimony and interpretability of the solutions. While the different fit statistics do not unanimously point to any particular solution, the four-class solution had generally achieved a good balance of high likelihood (low information criterion values), separation of classes (high entropy) and interpretability. The profiles of these classes of cognitive impairment are presented in Figure 1. The first class consisted of 27 participants who had high probabilities of presenting with impairment on the PSI, IMI, DMI, VFT and CTT, as well as moderate probabilities of presenting with impairment on the Stroop and Digit Span tests. This class was thus labeled "amnestic-dysexecutive." The second class consisted of 35 participants who had high probabilities of presenting with relatively isolated impairments on the Stroop test; this group was labeled "cognitively rigid." The third class consisted of 57 participants who were highly likely to be impaired on both the IMI and DMI; they were labeled "amnestic." The final and largest class consisted of 101 participants who were highly likely to present with an impairment on the digit span test and moderately likely to be impaired on the CTT, VFT and PSI. This group was labeled as "dysexecutive". These labels were determined according to our subjective interpretation of the data and were given for the purpose of facilitating subsequent references to these groups. It should be noted that although the VFT impairments have been subsumed under the "dysexecutive" label, we acknowledge that the controversy of conceptualizing the VFT (a category fluency test) as an executive function (Whiteside et al., 2016); VFT may relate more to temporal lobe functions than those of frontal-executive (Baldo, Schwartz, Wilkins, & Dronkers, 2006). The "dysexecutive" label relates mostly to the working memory and attentional impairments in these participants.

Between-group analyses

INSERT TABLE 2 HERE

These four groups were then compared via ANOVA and chi-square tests on the studied variables. The results of these analyses and descriptive statistics are presented in Table 2. All four groups were similar in terms of age, gender ratio, years of education and HADS scores. However they differed significantly on MoCA scores, $F(3, 216) = 7.64$; $p<.001$; Partial $\eta^2 =.096$. Specifically, post-hoc Tukey's tests revealed that the amnestic-dysexecutive group had significantly lower MoCA scores than the other three groups. The chi-square test also indicated that CDR ratings were different across all four groups, χ^2 (23 N=220)=0.32, p=.032; Cramer's V= .20. Post-hoc pairwise chi-square tests suggested that the amnestic-dysexecutive group was more likely to be given a CDR 0.5 rating relative to the cognitively rigid group, and the amnestic group was also more likely to be given a CDR 0.5 rating relative to the cognitively rigid and dysexecutive groups.

Discussion

The current report examined the different profiles of cognitive impairments and its associated functional status in an older-age community sample. Using a data-driven method, four distinct profiles of cognitive impairments emerged. Two different amnestic groups which were associated with impairments in immediate and delayed recall emerged from the data. The amnestic-dysexecutive group presented with co-occurring executive functions impairment, whereas the amnestic group had relatively isolated memory impairment. Two other non-amnestic profiles emerged as well; the cognitively rigid group was characterized by a relatively isolated cognitive inhibition deficit, and the dysexecutive group exhibited a cluster of other executive function-related deficits.

With regard to the two amnestic groups, similar "memory-impaired" profiles emerged in the other person-centered studies (Hanfelt et al., 2011; Lockwood et al., 2000; McGuinness et al., 2015), notwithstanding the fact that the comorbid impairment in other cognitive domains may differ across studies. The replication of these memory-impaired groups across multiple studies further validates the utility of the amnestic/nonamnestic MCI classification (Petersen, 2004). Next, the dysexecutive group reported in this study had also been similarly described in the other person-centered studies (Hanfelt et al., 2011; Lockwood et al., 2000). The replication of these cognitive impairment profiles in the current cultural context does suggest some cross-cultural generalizability in the patterns of cognitive impairment among older people. Though, it is difficult to make a strong conclusion on this aspect since the measures used and socio-demographics of the samples differ across studies. The cross-cultural generalizability of these cognitive profiles requires further examination in future research utilizing cross-cultural samples.

The cognitively rigid group appeared to have uniquely emerged from the current report; no other studies had documented such a profile. This is not surprising, considering that none of the other person-centered studies included a measure of cognitive inhibition in their models. Interestingly, this profile was characterized by a relatively isolated single-domain impairment. That is, participants in this group were unlikely to present with impairments in any other domains. This is consistent with Wolf et al.'s (2014) view that the Stroop interference is a qualitatively distinct cognitive impairment associated with aging. More specifically, they noted that the Stroop interference effect was significantly correlated with the diffusion tensor imaging (DTI) measures of mean diffusivity and fractional anisotropy in the white matter tracts of the corpus callosum, anterior corona radiata and anterior limb of internal capsule. However, these DTI measures did not correlate with performance on the Trail Making Test, a measure that taps into processes similarly assessed by the CTT and PSI in the current study. Taken together, these findings hinted at the idea that cognitive inhibition and its neural substrates were likely to be compromised in a relatively isolated manner, at least within a significant minority of cognitively impaired aged individuals. It will be interesting for future research to look at various environmental and biological variables that may explain such an isolated pattern of age-related impairment.Comparisons across the four different profiles revealed other significant findings. Even though the two amnestic groups did not significantly differ from the other two nonamnestic groups on self-reported functional impairment, these amnestic individuals are nevertheless more likely to have higher levels of clinician-rated impairment relative to their nonamnestic counterparts. The difference in findings between the self-reported and clinician-rated measures of impairment may reflect a lack of insight on the participant or inaccurate subjective perception of impairment in general. As a matter of fact, previous research has shown that cognitively impaired older people may not have an adequate awareness of their deficits (Vogel et al., 2004) and their self-reported deficits did not correlate with assessments carried out by the clinician (Arlt et al., 2008). In relation to the differences in clinician-rated impairments between the amnestic and non-amnestic groups, it should be noted that such quantitative findings may perhaps be an oversimplification of the actual picture, given that previous research has noted that amnestic and nonamnestic individuals with MCI tend to differ qualitatively in their functional impairments (Bangen et al., 2010). For instance, relative to cognitively healthy controls, participants with amnestic MCI were significantly impaired in abilities associated with financial management such as counting money and paying bills, whereas their nonamnestic MCI counterparts had significant impairment in abilities associated with health and safety such as assessing health problems and dealing with medical emergencies. Perhaps future studies may consider using a combination of measures to assesses functional status across multiple domains to further understand the nature of functional impairments in these different cognitive profiles.

We also showed that the amnestic-dysexecutive group had significantly worse general cognitive functioning as assessed on the MoCA relative to the other three groups. This is expected given the relatively wide-ranging cognitive deficits presented by participants from this group. Finally, it should be noted that the four groups were similar in terms of demographics and psychoaffective variables; hence, these variables could not account for the different profiles and their differences in clinician-rated impairments.

These findings present important implications for the clinical context and future research. Firstly, the conceptualization of these cognitive impairments profiles will facilitate future researchers in studying how they may be related to an underlying etiology. These profiles relate to not just to a single cognitive variable but a cluster of cognitive impairments; hence, relative to the individual cognitive markers reported in variable-centered studies, these profiles might serve as more specific markers to the various underlying etiologies associated with cognitive impairments. Ultimately, this will enable such profiles of cognitive impairments to be recognized as likely prodromal states of specific diseases associated with cognitive decline, like Alzheimer's disease and frontotemporal dementia (Hanfelt et al., 2011), such that early intervention for these conditions can be considered and undertaken to prevent or delay further cognitive decline (Cooper et al., 2015). Secondly, given the heterogeneity in cognitive impairments among older people, the needs of such populations could not be addressed using a one-size-fits-all approach. There is a need to identify the different patterns of cognitive impairments such that specific interventions can be efficiently designed or developed to remediate the different clusters of cognitive impairments. Thirdly, given that participants with executive functions impairments (the amnestic-dysexecutive, cognitively rigid and dysexecutive groups combined) formed the majority of our included participants, our report emphasizes the need for clinicians to pay greater attention to non-memory related cognitive impairment. This is especially since MCI literature is disproportionately focused on memory impairments and relatively less attention has been given to executive function-related deficits (Tales, Wilcock, Phillips, & Bayer, 2014). Finally, the fact that the cognitive inhibition emerged as a relatively isolated impairment in the current report highlights the need for neuropsychological assessments to include at least a measure of cognitive inhibition. Such an impairment would otherwise go unnoticed, especially in the context of MCI diagnosis; consequently, participants with these impairments would be rendered as false negative cases.

The current report is subjected to a few limitations. First, cognitive impairment in this study was not operationalized in terms of MCI diagnoses, which would have been useful to relate to the vast literature on MCI. Although all of the included participants would have met the objective cognitive impairment criteria of MCI, not all were assessed to have met the other criteria for MCI. Secondly, the determination of the cognitively rigid profile rested solely on Stroop interference. This makes the model excessively prone to some of the weaknesses associated with this Stroop measure. For instance, there is some controversy surrounding the confounding influence of reading speed on the interference score; participants who read faster would require more effort to suppress the dominant response of saying out the word (Chafetz & Matthews, 2004). Hence, future person-centered research may want to attempt the replication of such cognitive profile using a combination of other inhibition-related measures, such as the go/no-go, stop-signal and flanker tests. Finally, the relatively small sample sizes of the amnestic-dysexecutive and cognitively rigid groups may have limited statistical power in detecting between-group differences in the variables studied.

Conflict of Interests

The authors have no competing interests to report.

References

Arlt, S., Hornung, J., Eichenlaub, M., Jahn, H., Bullinger, M., & Petersen, C. (2008). The patient with dementia, the caregiver and the doctor: cognition, depression and quality of life from three perspectives. *International Journal of Geriatric Psychiatry*, *23*(6), 604–610. https://doi.org/10.1002/gps.1946

Baldo, J. V, Schwartz, S., Wilkins, D., & Dronkers, N. F. (2006). Role of frontal versus temporal cortex in verbal fluency as revealed by voxel-based lesion symptom mapping. *International Journal of the Neuropsychological Society*, *12*. https://doi.org/10.1017/S1355617706061078

Bangen, K. J., Jak, A. M. Y. J., Schiehser, D. M., Delano-Wood, L., Tuminello, E., Han, S. D., … Bondi, M. W. (2010). Complex activities of daily living vary by mild cognitive impairment subtype. *Journal of the International Neuropsychological Society : JINS*, *16*(4), 630–639. https://doi.org/10.1017/S1355617710000330

Busse, A., Hensel, A., Gühne, U., Angermeyer, M. C., & Riedel-Heller, S. G. (2006). Mild cognitive impairment: Long-term course of four clinical subtypes . *Neurology* , *67*(12), 2176–2185. https://doi.org/10.1212/01.wnl.0000249117.23318.e1

Chafetz, M. D., & Matthews, L. H. (2004). A New interference score for the Stroop test. *Archives of Clinical Neuropsychology*, *19*(4), 555–567. https://doi.org/http://dx.doi.org/10.1016/j.acn.2003.08.004

Cooper, C., Sommerlad, A., Lyketsos, C. G., & Livingston, G. (2015). Modifiable predictors of dementia in mild cognitive impairment: A systematic review and meta-analysis. *American Journal of Psychiatry*, *172*(4), 323–334. https://doi.org/10.1176/appi.ajp.2014.14070878

Craik, F. I. M., & Rose, N. S. (2012). Memory encoding and aging: A neurocognitive perspective. *Neuroscience & Biobehavioral Reviews*, *36*(7), 1729–1739.

https://doi.org/http://dx.doi.org/10.1016/j.neubiorev.2011.11.007

D’Elia, F., Satz, P., & Uchiyama, C. (1994). *Color trails: Adult form manual*. Odessa, FL: Psychological Assessment Resources.

Hanfelt, J. J., Wuu, J., Sollinger, A. B., Greenaway, M. C., Lah, J. J., Levey, A. I., & Goldstein, F. C. (2011). An exploration of subgroups of mild cognitive impairment based on cognitive, neuropsychiatric and functional features: analysis of data from the National Alzheimer’s Coordinating Center. *The American Journal of Geriatric Psychiatry : Official Journal of the American Association for Geriatric Psychiatry*, *19*(11), 940–50. https://doi.org/10.1097/JGP.0b013e31820ee9d2

Hughes, C. P., Berg, L., Danziger, W. L., Coben, L. A., & Martin, R. (1982). A new clinical scale for the staging of dementia. *The British Journal of Psychiatry*, *140*(6), 566–572.

Lam, C. L. K., Pan, P.-C., Chan, A. W. T., Chan, S.-Y., & Munro, C. (1995). Can the Hospital Anxiety and Depression (HAD) Scale be used on Chinese elderly in general practice? *Family Practice* , *12*(2), 149–154. https://doi.org/10.1093/fampra/12.2.149

Lee, T. M. C., & Chan, C. C. H. (2000). Stroop Interference in Chinese and English. *Journal of Clinical and Experimental Neuropsychology*, *22*(4), 465–471. https://doi.org/10.1076/1380-3395(200008)22:4;1-0;FT465

Lee, T. M. C., Yuen, K. S. L., & Chan, C. C. H. (2002). Normative Data for Neuropsychological Measures of Fluency, Attention, and Memory Measures for Hong Kong Chinese. *Journal of Clinical and Experimental Neuropsychology*, *24*(5), 615–632. https://doi.org/10.1076/jcen.24.5.615.1001

Leung, N. T. Y., Tam, H. M. K., Chu, L. W., Kwok, T. C. Y., Chan, F., Lam, L. C. W., … Lee, T. M. C. (2015). Neural plastic effects of cognitive training on aging brain, *2015*, 1–26. Retrieved from http://scholar.google.com/scholar_url?url=http://downloads.hindawi.com/journals/np/aip/535618.pdf&hl=en&sa=X&scisig=AAGBfm0UGN3c5D3eAQ-oVOL-Zuahzy-cwg&nossl=1&oi=scholaralrt

Linzer, D. A., & Lewis, J. B. (2011). poLCA: An R package for polytomous variable latent class analysis. *Journal of Statistical Software*, *42*(10), 1–29.

Lockwood, K. A., Alexopoulos, G. S., Kakuma, T., & Van Gorp, W. G. (2000). Subtypes of Cognitive Impairment in Depressed Older Adults. *The American Journal of Geriatric Psychiatry*, *8*(3), 201–208. https://doi.org/http://dx.doi.org/10.1097/00019442-200008000-00004

Manly, J. J., Tang, M.-X., Schupf, N., Stern, Y., Vonsattel, J.-P. G., & Mayeux, R. (2008). Frequency and course of mild cognitive impairment in a multiethnic community. *Annals of Neurology*, *63*(4), 494–506. https://doi.org/10.1002/ana.21326

McGuinness, B., Barrett, S. L., McIlvenna, J., Passmore, A. P., & Shorter, G. W. (2015). Predicting conversion to dementia in a memory clinic: A standard clinical approach compared with an empirically defined clustering method (latent profile analysis) for mild cognitive impairment subtyping. *Alzheimer's and Dementia: Diagnosis, Assessment and Disease Monitoring*, *1*(4), 447–454. https://doi.org/10.1016/j.dadm.2015.10.003

Montejo, P., Montenegro, M., Fernández, M. A., & Maestú, F. (2012). Memory complaints in the elderly: Quality of life and daily living activities. A population based study. *Archives of Gerontology and Geriatrics*, *54*(2), 298–304. https://doi.org/http://dx.doi.org/10.1016/j.archger.2011.05.021

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., … Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A Brief Screening Tool For Mild Cognitive Impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Petersen, R. C. (2004). Mild cognitive impairment as a diagnostic entity. *Journal of Internal Medicine*, *256*(3), 183–194. https://doi.org/10.1111/j.1365-2796.2004.01388.x

Petersen, R. C., Caracciolo, B., Brayne, C., Gauthier, S., Jelic, V., & Fratiglioni, L. (2014). Mild cognitive impairment: A concept in evolution. *Journal of Internal Medicine*, *275*(3), 214–228. https://doi.org/10.1111/joim.12190

Philippot, P., & Agrigoroaei, S. (2016). Repetitive thinking, executive functioning, and depressive mood in the elderly. *Aging & Mental Health*, 1–5. https://doi.org/10.1080/13607863.2016.1211619

Prince, M., Wimo, A., Guerchet, M., Ali, G., WU, Y., & Prina, M. (2015). World Alzheimer Report 2015 The Global Impact of Dementia. Alzheimer's Disease International. Retrieved from https://www.alz.co.uk/research/WorldAlzheimerReport2015.pdf

Spina, L. M. R., Ruff, R. M., & Mahncke, H. W. (2006). *Cognitive Self-Report Questionnaire (CSRQ) Manual*. San Francisco, CA: Posit Science Corporation.

Spreen, O., & Strauss, E. A. (1998). *A compendium of neuropsychological tests: Administration, norms, and commentary* (2nd ed). New York: Oxford University Press.

Tales, A., Wilcock, G. K., Phillips, J. E., & Bayer, A. (2014). Is there more to subjective cognitive impairment than meets the eye? A perspective. *Journal of Alzheimer's Disease : JAD*, *41*(3), 655–661. https://doi.org/10.3233/JAD-132414

Tulsky, D. S., Chelune, G. J., & Price, L. R. (2004). Development of a New Delayed Memory Index for the WMS-III. *Journal of Clinical and Experimental Neuropsychology*, *26*(4), 563–576. https://doi.org/10.1080/13803390490490782

Vogel, A., Stokholm, J., Gade, A., Andersen, B. B., Hejl, A.-M., & Waldemar, G. (2004). Awareness of Deficits in Mild Cognitive Impairment and Alzheimer's Disease: Do MCI Patients Have Impaired Insight? *Dementia and Geriatric Cognitive Disorders*, *17*(3), 181–187. Retrieved from http://www.karger.com/DOI/10.1159/000076354

Wechsler, D. (1997). *WAIS-III: Administration and scoring manual: Wechsler adult intelligence scale*. Psychological Corporation.

Wechsler, D. (1997). Wechsler Memory Scale- (Third Ed.). *The Psychological Corporation.*

Whiteside, D. M., Kealey, T., Semla, M., Luu, H., Rice, L., Basso, M. R., & Roper, B. (2016). Verbal Fluency: Language or Executive Function Measure? *Applied Neuropsychology: Adult*, *23*(1), 29–34. https://doi.org/10.1080/23279095.2015.1004574

Wolf, D., Zschutschke, L., Scheurich, A., Schmitz, F., Lieb, K., Tüscher, O., & Fellgiebel, A. (2014). Age-related increases in stroop interference: Delineation of general slowing based on behavioral and white matter analyses. *Human Brain Mapping*, *35*(5), 2448–2458. https://doi.org/10.1002/hbm.22340

Wong, A., Xiong, Y. Y., Kwan, P. W. L., Chan, A. Y. Y., Lam, W. W. M., Wang, K., … Mok, V. C. T. (2009). The Validity, Reliability and Clinical Utility of the Hong Kong Montreal Cognitive Assessment (HK-MoCA) in Patients with Cerebral Small Vessel Disease. *Dementia and Geriatric Cognitive Disorders, 28*(1), 81–87. Retrieved from http://www.karger.com/DOI/10.1159/000232589

Yu, J., Lam, C. L. M., & Lee, T. M. C. (2016). Perceived loneliness among older adults with mild cognitive impairment. *International Psychogeriatrics*, 1–5. https://doi.org/10.1017/S1041610216000430

Yuan, P., & Raz, N. (2014). Prefrontal cortex and executive functions in healthy adults: A meta-analysis of structural neuroimaging studies. *Neuroscience & Biobehavioral Reviews*, *42*, 180–192. https://doi.org/http://dx.doi.org/10.1016/j.neubiorev.2014.02.005

Zigmond, A. S., & Snaith, R. P. (1983). The hospital anxiety and depression scale. *Acta Psychiatrica Scandinavica.*, *67*(6), 361–370.

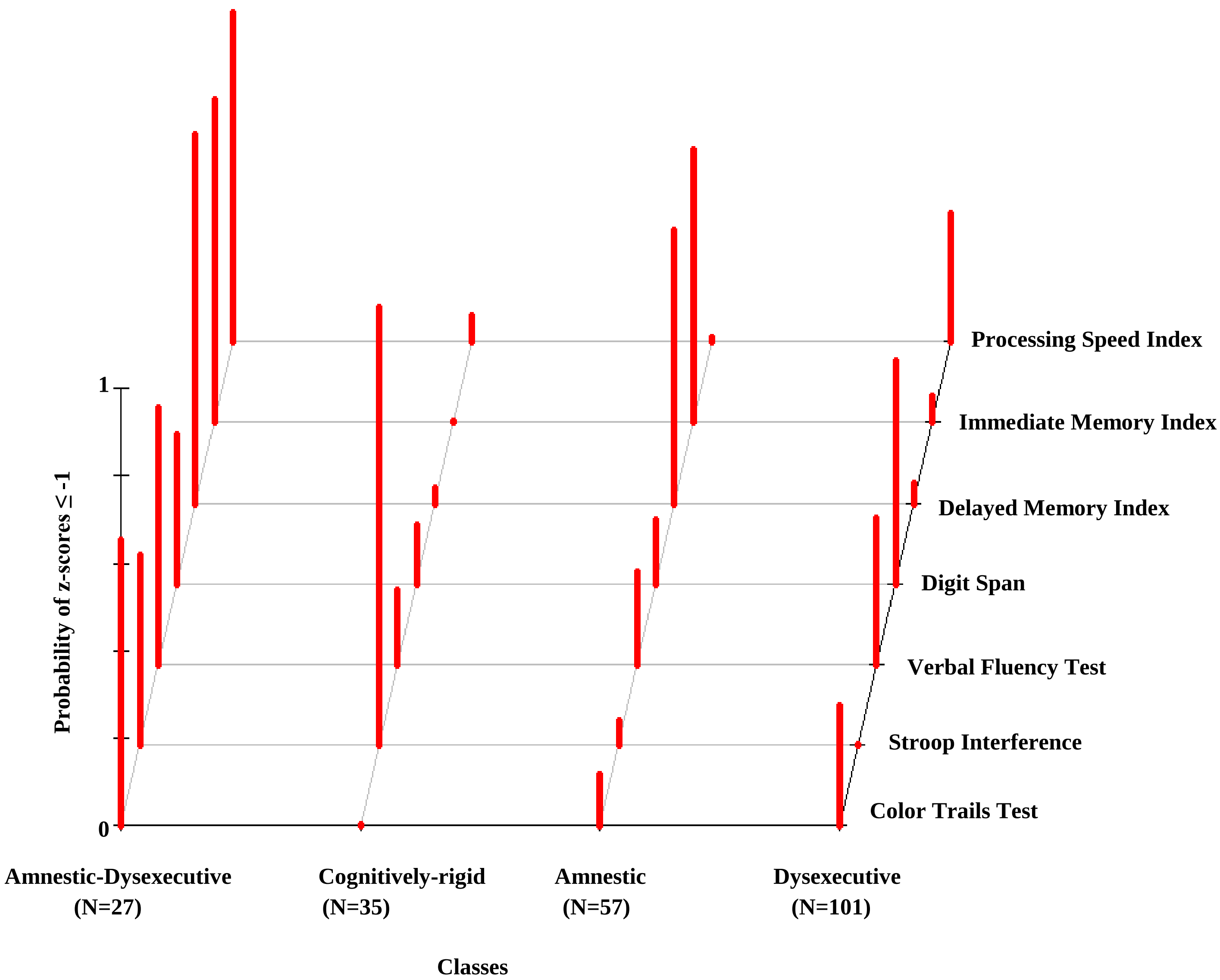

Figure 1. Profiles of cognitive impairments

Table 1. Fit statistics of LCA solutions

No. of classes	**Residual df**	**AIC**	**BIC**	**aBIC**	**cAIC**	**Entropy**
1	120	1826	1850	1789	1857	-
2	112	1785	1836	1789	1851	0.761
3	104	1763	1841	1768	1864	0.862
4	96	1743	1849	1750	1880	0.908
5	88	1724	1856	1733	1895	0.778
6	80	1720	1879	1730	1926	0.811

Note. df= degrees of freedom; AIC=Akaike Information Criterion; BIC= Bayesian Information Criterion, aBIC=adjusted Bayesian Information Criterion; cAIC= consistent Akaike Information Criterion.

Table 2. Descriptive statistics and between group statistics

	Groups				Between group statistics		Post-hoc tests[a]
	1. Amnestic-dysexecutive	**2. Cognitively-rigid**	**3. Amnestic**	**4. Dysexecutive**	$F_{(2,141)}$	χ^2	
Demographics							
Mean age (SD)	70.6 (7.4)	70.6 (5.6)	69.9 (7.0)	71.7 (6.3)	6.31		
Gender							
Males	9	12	17	24		2.05	
Females	18	23	40	77			
Mean years of education (SD)	8.4 (4.0)	9.2 (4.8)	8.8 (4.0)	7.77 (4.5)	4.73		
Psychiatric measures							
Mean HADS depression (SD)	4.7 (2.5)	4.2 (2.7)	4.6 (2.9)	4.5 (3.1)	.58		
Mean HADS anxiety (SD)	4.8 (3.1)	4.1 (2.8)	4.7 (3.4)	4.2 (3.0)	.23		
Mean MoCA (SD)	19.6 (3.4)	23.2 (2.7)	22.0 (3.0)	22.0 (2.9)	13.74**		1 < 2, 3 & 4
Functional impairment							
Mean CSRQ (SD)							
Social	25.2 (6.1)	24.4 (5.8)	26.7 (8.5)	24.9 (5.7)	1.91		
Cognitive	29.6 (5.7)	28.9 (6.4)	28.4 (6.9)	27.9 (5.6)	.04		
CDR frequency counts							
CDR 0	15	28	33	75		8.78*	1 ≠ 2, 3 ≠ 2, 3 ≠ 4
CDR 0.5	12	7	24	26			

Note. HADS= Hospital Anxiety MoCA= Montreal Cognitive Assessment; CSRQ= Cognitive Self-Report Questionnaire; CDR= Clinical Dementia Rating. [a]Significant F and χ^2 statistics were followed up with Bonferroni and pairwise χ^2 tests respectively. *p <.05. ** p <.001