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Changes in cognitive function among older adults: A latent profile transition analysis

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ABSTRACT

Cognitive decline in late life is a crucial health problem. It is important to understand the consistency and change of older adults' cognitive function in late life. Data for older adults (78 years and above) from the Health and Retirement Study (N = 1680) were used to explore meaningful subtypes of cognitive function and transitions patterns between those profiles across times. Age, gender, levels of education and nursing home were incorporated as covariates to explore the association between these variables and cognitive function transition pattern. Three cognitive function subgroups (Normal Cognitive Function, Fluid Intelligence Impairment and Cognitive Impairment) were identified. Individuals in Normal Cognitive Function status had a high probability to convert to the Fluid Intelligence Impairment status whereas the Cognitive Impairment status appeared a predominant tendency for stability. Increasing age played a significant role in fluid intelligence impairment and cognitive impairment process. Female and individuals with nursing home might be at higher risk of subsequent fluid intelligence impairment, while higher education did not protect against fluid intelligence impairment. These findings highlighted the usefulness to adopt a person-centered approach rather than a variable-centered approach, suggesting directions for future research and tailored interventions approaches to older adults with particular characteristics.

1. Introduction

U.S. national statistics indicate that the number of individuals over the age of 65 expected to double in the next 25 years (Kinsella & Wan, 2009). However, with the population aging, improvements in life expectancy have resulted in a large number of older adults with a high risk of cognitive decline (Crimmins, Saito, & Kim, 2016; Freedman, Aykan, & Martin, 2001; Karlamangla et al., 2009; Ofstedal, Zimmer, & Lin, 1999; Suthers, Kim, & Crimmins, 2003). According to some studies, about 22% of older adults aged 75 and older had cognitive impairment but not dementia (Plassman et al., 2008), while about 50% of older adults aged 75 and older had Alzheimer's disease dementia (Hebert, Weuve, Scherr, & Evans, 2013). Cognitive decline in late life is a crucial health problem, which is closely associated with physical health, psychological health and quality of life among older adults (Cigolle, Langa, Kabeto, Tian, & Blaum, 2007; Rosano et al., 2005).

Longitudinal studies have shown significant declines in cognitive function with increasing age. However, numerous studies have found that many older adults show dramatic deterioration whereas others experience little change or even remain relatively stable over time (Hultsch, MacDonald, Hunter, Levy-Bencheton, & Strauss, 2000; Christensen et al., 2001; Wilson et al., 2002; de Frias, Dixon, & Strauss, 2009). Moreover, researchers have focused on longitudinal age-related effects in more specific cognitive process. For example, studies have found that older adults perform more poorly than young adults in general executive functions such as inhibition, manipulation and switching (Kray & Lindenberger, 2000; Cepeda, Kramer, & Gonzalez de Sather, 2001; Reimers & Maylor, 2005; Head, Kennedy, Rodrigue, & Raz, 2009). Besides, studies have shown significant declines in cognitive abilities such as working memory and encoding new memories of information, while short-term memory and semantic knowledge remain stable (Hedden & Gabrieli, 2004). Similarly, studies have also documented that "crystal1ized" abilities such as vocabulary tend to be stable, while "fluid" abilities such as tests requiring new learning show substantial declines with advancing age (Craik, 1990; Giambra, Arenberg, Kawas, Zonderman, & Costa, 1995; Hultsch, Hertzog, Small, McDonald-Miszczak, & Dixon, 1992; McArdle, Ferrer-Caja, Hamagami, & Woodcock, 2002; Salthouse, 2010; Tucker-Drob, 2011). These results show that longitudinal changes in cognitive function is not a uniform process but a heterogeneous one (Goh, An, & Resnick, 2012).

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Studies often assess individuals' cognitive function by self-report instruments such as the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), or the Telephone Interview for Cognitive Status (TICS; Brandt, Spencer, & Folstein, 1988). Such approaches only focus on variability in the total score and not on the specific patterns of cognitive function. Besides, studies have revealed that individuals' cognitive function status were not stable because there was a decline in cognitive function as older adults aged (Mehta, Yaffe, & Covinsky, 2002; Alley, Suthers, & Crimmins, 2007; Saczynski et al., 2015; Whitlock et al., 2017). It is important to understand the consistency and change of older adults' cognitive function in late life.

Most researches combine cognition scores into a single composite score as a measure may not offer a full picture of older adults' cognitive function profiles. Departing from conventional approaches to investigating cognitive function, some researchers have suggested that older adults can be assigned to latent profiles of cognitive function which demonstrate similar cognitive function patterns (Amano, Park, & Morrow-Howell, 2017; Morin & Midlarsky, 2017). Latent profile analysis (LPA) is a multivariate statistical technique that identifies a latent profile which can be inferred from a set of indicators (Lanza, Patrick, & Maggs, 2010). Typically, the variable-centered research design often explicates the relationships between latent variables and assumes this relationship holds for everyone (Collins & Lanza, 2009; Fryer, 2017). However, LPA focuses on the relationships between individuals rather than variables. LPA allows us to categorize individuals into probability-based profiles where individuals have similar characteristics (Collins & Lanza, 2009; Muthén & Muthén, 2002). And in LPA, latent profiles may provide a better way to represent stable sets of characteristics (cognitive function profiles) of older adults in late life.

To account for multiple aspects of the cognitive function and natural heterogeneity in a large sample, a person-centered longitudinal analytical method is necessary. Of importance, LPA can be extended to model longitudinal data called latent profile transition analysis (LPTA). LPTA is a flexible analytical tool for both cross-sectional and longitudinal person-centered research, which can estimate both group membership and the transition between these subgroups across time (Fryer, 2017). In LPTA, the emphasis is estimating the transitions over time in latent profile membership (Lanza et al., 2010; Martinent & Decret, 2015), allowing us to shed light on the issue of stability or change of cognitive function profiles among subtypes over time.

Considering predictors of profiles cognitive function is important for detecting the individuals who are at greatest risk. It was well established that cognitive function was associated with age (Li & Hsu, 2015; McArdle, Fisher, & Kadlec, 2007), gender (Ofstedal et al., 1999; Suthers et al., 2003), levels of education (Cagney & Lauderdale, 2002; Lièvre, Alley, & Crimmins, 2008), and nursing home (Clark et al., 2013). Available studies have unanimously demonstrated that age is the strongest risk factor for cognitive decline (Boot et al., 2013; Li & Hsu, 2015; McArdle et al., 2007; Stephan, Sutin, Luchetti, & Terracciano, 2016). The prevalence of cognitive impairment in the population differs by gender, indicating that females tend to bear greater cognitive impairment than males (Ofstedal et al., 1999; Suthers et al., 2003). In addition, higher education levels are associated with better cognitive performance (Cagney & Lauderdale, 2002; Lièvre et al., 2008). Finally, having nursing has been shown to predict better cognitive performance (Clark et al., 2013). Understanding the association between these variables and cognitive function transition pattern is useful not only for theorists but also for practitioners who help to improve diagnostic practices and design tailored interventions. In order to find out whether these person-specific factors were associated with cognitive function profile and transition pattern, we also report analyses of the following baseline variables which are associated with cognitive function profiles and transition probabilities: *Age, Gender, Levels of education* and *Nursing home*.

In order to classify the older adults according to their changes in cognitive function over time and explore demographic characteristics associated with specific subtypes of cognitive function, our research had two objectives: (1) to explore distinct unique profiles of cognitive function over four years and, (2) to examine which baseline variables affect cognitive function profiles and transition patterns.

2. Method

2.1. Participants

The data used in this study were derived from three waves of the Health and Retirement Study (HRS), collected in 2010, 2012 and 2014. The HRS, a national representative longitudinal study of older adults aged 50 or older in the United States was sponsored by the National Institute on Aging and conducted by the University of Michigan, and the data are available at http://hrsonline.isr.umich.edu/ (Amano et al., 2017; Donovan et al., 2017). Participants were interviewed face to face or over the telephone every two years from 1992 to 2014, which included a cognitive function assessment. In this study, sample loss and missing values on baseline variables such as gender were excluded. The longitudinal cohort study contained a total of 1680 respondents, aged from 78 to 118, an average of 10.38 years of education, 61.01% were female, and 79.64% were White.

2.2. Assessments

2.2.1. Cognitive function

Cognitive Function was assessed by a standardized measure of the Telephone Interview for Cognitive Status (TICS), which has been used as a cognitive screening instrument in many studies with satisfactory validity (Crimmins, Kim, Langa, & Weir, 2011; Fong et al., 2009; Knopman et al., 2010; Esther van den Berg et al., 2012; Clark et al., 2013; Saczynski et al., 2015; Amano et al., 2017). The TICS included measures of (1) Immediate recall of 10 words from four different lists (0 to 10 points); (2) Delayed recall of 10 words after the immediate recall (0 to 10 points); (3) Serial sevens subtraction from 100 for five trials (0 to 5 points); (4) Backward counting from 20 (0 to 2 points); (5) Identification and naming, including object identification, date identification, U.S. president and vice president naming by last name (0 to 8 points). The procedure of the TICS was as follow: Firstly, respondents were asked to repeat as many as they could immediately after the interviewer read a list of 10 words and to repeat again several minutes later for both immediate and delayed recall tests. Secondly, respondents were asked to subtract 7 from 100 for five times. Then, respondents were asked to finish the identification and naming test. Finally, respondents were asked to count backward from 20. Rodgers, Ofstedal, and Herzog, (2003) created a measure of cognitive function by using a composite score summing all the items, which can range from 0 to 35, and higher scores indicate better cognitive function. Greatest lower bound algebraic (reliability) coefficients for the overall score range from 0.97 to 0.98 across the three waves (Trizano-Hermosilla & Alvarado, 2016).

2.2.2. Covariates

Table 1 provides descriptive statistics for all covariates used included in analyses. The covariates data were measured at Time 1, and dichotomized into different groups (Ardila, Solis, Rosselli, & Gómez, 2000; Clark et al., 2013), covering (1) Age (1 = 78–87, 2 = 88–97, 3 = 98+); (2) Gender (0 = male, 1 = female); (3) Levels of education (1 = 0–4 years, 2 = 5–8 years, 3 = 9–16 years, 4 = years > 16); (4) Nursing home (0 = no, 1 = yes).

2.3. Analytic strategy

LPA were used to explore a measurement model accurately select the meaningful latent statues of cognitive function profile at each wave. There were some commonly used statistical fit indices in LPA to decide

Table 1
Descriptive statistics of all covariates used in LPTA ($N = 1680$).

Covariates	Code	Label	Frequency (Valid %)
Age	1	78–87	38.45%
	2	88–97	44.64%
	3	98+	16.91%
Gender	0	male	38.99%
	1	female	61.01%
Levels of education	1	0–4 years	10.36%
	2	5–8 years	21.13%
	3	9–16 years	62.86%
	4	> 16 years	5.65%
Nursing home	0	No	87.56%
	1	yes	12.44%

on the best fitting model: Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), the consistent Akaike Information Criterion (cAIC), adjusted BIC (aBIC) and entropy (Akaike, 1987; Bozdogan, 1987; Ramaswamy, Desarbo, Reibstein, & Robinson, 1993; Schwarz, 1978; Sclove, 1987). Smaller IC values and higher entropy values indicates a better fit model.

LPTA was applied to describe change of cognitive function over time, where transitions over time in latent profile membership were estimated. LPTA was an extended model of LPA for longitudinal data (Martinent & Decret, 2015). Instead of latent profile, latent status was used to indicate how the prevalence of latent profile membership changed across time (Ni, Tein, Zhang, Yang, & Wu, 2017). Also, the transition probabilities of LPTA described how the older adults transition across time in cognitive function profiles.

Multinomial logistic regression analysis was used to explore whether covariates affected the change in cognitive function. Then, age, gender, levels of education and nursing home were incorporated as covariates of cognitive function profiles.

Latent profile analyses and latent transition analyses were fit using Mplus version 6.1 (Muthén & Muthén, 2012). Descriptive statistics and multinomial logistic regression analysis were using SPSS version 17.0 (IBM SPSS Statistics, Armonk, USA).

3. Results

Of the 1680 respondents, the mean age was 90.1 years (SD: 7.28; range 78–118), the mean levels of education was 10 years, 655 (38.99%) were male and 1338 (79.64%) were White. Of the total sample, 209(12.44%) were with nursing home.

3.1. Cross-sectional latent profile analyses of cognitive function in older adults

First, Cross-sectional LPA was performed for three waves. Fit indices indicated that the five-class model provides the best fit for T1, T2 and T3 data (see Table 2). Although five-class had lower IC values, the three-class model had the highest Entropy values. On the other hand, heterogeneity between classes is reduced as classes are added (Ni et al., 2017). It is important to consider not only the consistency across three times but also the simplicity of the model. To reach the balance between theoretical and statistical considerations (Martinent & Decret, 2015), the three class model was chosen. Lubke and Muthén (2007) proposed that Entropy values should be around 0.80 and above, which means at least 90% correct assignment.

The cognitive function profiles were consistent in three waves (see Figs. 1–3). Descriptive labels for cognitive function profiles were: *Normal Cognitive Function* with high scores of all TICS measures; *Cognitive Impairment* with low scores of all TICS measures; *Fluid Intelligence Impairmen*t with low scores of the measure of backward counting from 20 and moderate scores of the other TICS measures.

Table 3 provided the prevalence of each cognitive function profile at Time 1, Time 2 and Time 3. Although the results are based on the cross-sectional analyses, they can be used to describe the types of change among the cognitive function from an inter-individual prospective. The *Normal Cognitive Function* profile contained the largest percentage of older adults for three waves, which were 87.90%, 82.89% and 79.03% respectively. The proportion of the *Fluid Intelligence Impairmen*t profile increased over time, which was 10.30%, 15.00% and 17.56% respectively. The percentage of the *Cognitive Impairment* profile stabilized across time, which was 1.80%, 2.11% and 3.41% respectively.

3.2. Latent profile transition analyses of cognitive function in older adults

3.2.1. Measurement invariance across time

The transition probabilities (see Table 4) reflected the probability of exhibiting a particular cognitive function profile at Time t + 1 conditional on Time t cognitive function profile. Thus, diagonal elements reflected the proportion of older adults with the same cognitive function profile at three times. For example, individuals in *Normal Cognitive Function* latent status at Time 1 had a probability of 0.22 of still being classified as *Normal Cognitive Function* latent status at Time 2. Similarly, individuals in *Cognitive Impairment* latent status at Time 2 had a high probability of still being classified as same class at Time 3(transition probability = 1.00), which means that nobody transitioned to *Normal Cognitive Function* or *Fluid Intelligence Impairment* latent status. Nevertheless, some individuals have exhibited changes in their combinations of cognitive function. Individuals from the *Normal Cognitive Function* latent status at T1 and T2 were at most risk of advancing to the *Fluid Intelligence Impairmen*t latent status at T2 (transition probability = 0.47) and T3 (transition probability = 0.34). Participants in *Fluid Intelligence Impairment* latent status at Time 2 had a probability of 0.62 of remaining in that latent status at Time 3, while they had a probability of advancing to the *Cognitive Impairment* latent status at Time 3 (transition probability = 0.31), and a little probability of advancing to the *Normal Cognitive Function* latent status at Time 3 (transition probability = 0.07). In summary, the whole results suggested that cognitive function profiles exhibited both stability and changes.

3.2.2. Incorporating covariates

Four covariates (*Age, Gender, Levels of education and Nursing home*) were added into this LPTA model to explore whether individual characteristics affected the transitions in cognitive function from time to time.

The covariate effect estimates (see Table 5) showed that there were significant effects of age and levels of education on the *Fluid Intelligence Impairment* and *Cognitive Impairment* profiles as compared with the *Normal Cognitive Function* profile at T1. Logistic regression coefficient of age (1.49, $p < .001$; 1.52, $p < .001$) and levels of education(0.66, $p < .001$; -0.48, $p < .001$) indicated there were significant differences between these profiles of older adults in the *Fluid Intelligence Impairment* and *Cognitive Impairment* profiles compared with the *Normal Cognitive Function* profile. For a one-unit increase in age, the odds of being in the *Fluid Intelligence Impairment* and *Cognitive Impairment* profiles compared with the *Normal Cognitive Function* profile increased, after controlling for gender and nursing home. Older adults who had higher levels of education were significantly less likely to be in the *Cognitive Impairment* profile compared with the *Normal Cognitive Function* profile, and more likely to be in the *Fluid Intelligence Impairment* profile. Besides, Individuals who were females (0.36, $p < 0.05$) had an increase in the odds of being in the *Fluid Intelligence Impairment* profile compared with the *Normal Cognitive Function* profile.

The logistic regression coefficients of age (1.79, $p < .001$; 1.40, $p < .001$) at T2 indicated that for a one-unit increase in this covariate, there were significant increases in the odds of being in the *Fluid Intelligence Impairment* and *Cognitive Impairment* profiles compared with the *Normal Cognitive Function* profile. Individuals who were females (0.62, $p < .001$) had an increase in the odds of being in the *Fluid*

Table 2
Fit indices for LPA models with 1–5 classes in the three waves.

	No. of classes				
	1	2	3	4	5
No. of free parameters	10	21	32	43	54
Time 1 (2010)					
AIC	23853.17	−32733.52	**−37683.20**	−39911.26	−41552.96
BIC	23907.43	−32619.56	**−37509.55**	−39677.92	−41259.92
cAIC	23917.43	−32598.56	**−37477.55**	−39634.92	−41205.92
aBIC	23875.66	−32686.27	**−37611.21**	−39814.53	−41431.47
Entropy	N/A[a]	0.94	**0.97**	0.96	0.87
Time 2 (2012)					
AIC	23853.17	−36171.49	**−40788.36**	−42982.04	−44746.84
BIC	23907.43	−36057.53	**−40614.71**	−42748.69	−44453.80
cAIC	23917.43	−36036.53	**−40582.71**	−42705.69	−44399.80
aBIC	23875.66	−36124.25	**−40716.37**	−42885.30	−44625.35
Entropy	N/A[a]	0.92	**0.95**	0.90	0.86
Time 3 (2014)					
AIC	23853.17	−40247.37	**−44503.24**	−46838.85	−48502.14
BIC	23907.43	−40133.41	**−44329.59**	−46605.51	−48209.10
cAIC	23917.43	−40112.41	**−44297.59**	−46562.51	−48155.10
aBIC	23875.66	−40200.12	**−44431.25**	−46742.11	−48380.65
Entropy	N/A[a]	0.93	**0.94**	0.86	0.84

Bold entries reflect selected model. [a] Entropy not available for the one-class model.

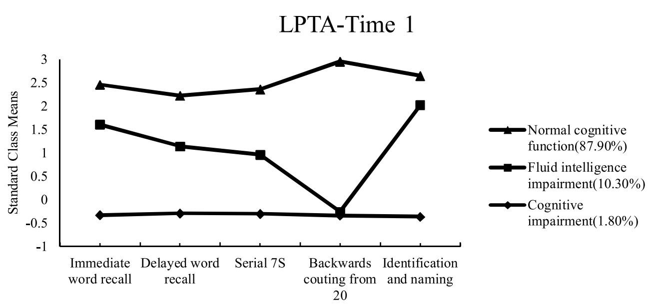

Fig. 1. Standard class means for three class solution in 2010.

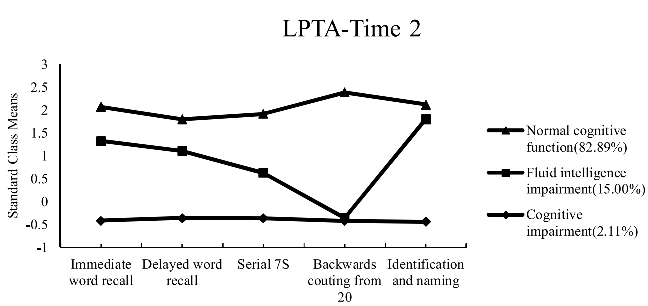

Fig. 2. Standard class means for three class solution in 2012.

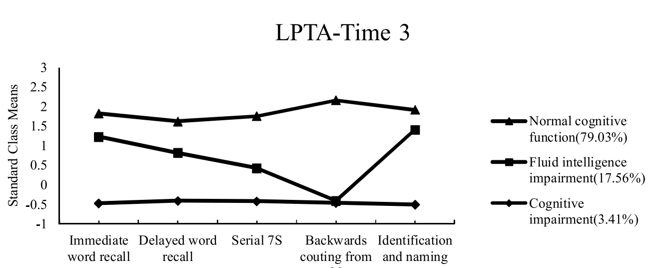

Fig. 3. Standard class means for three class solution in 2014.

Intelligence Impairment profile compared with the *Normal Cognitive Function* profile. And older adults with nursing home were less likely to in the *Fluid Intelligence Impairment* profile compared with the *Normal Cognitive Function* profile. There were significant effects of levels of education on the *Fluid Intelligence Impairment* and *Cognitive Impairment* profiles as compared with the *Normal Cognitive Function* profile. For a one-unit increase in levels of education, the odds of being in the *Fluid Intelligence Impairment* profile compared with the *Normal Cognitive Function* profile increased. Nevertheless, older adults who had higher levels of education were less likely to be in the *Cognitive Impairment* profile compared with the *Normal Cognitive Function* profile.

As Table 5 showed at T3, relative to the *Normal Cognitive Function*

Table 3
Three-status model of cognitive function in T1-T3.

	Latent Status		
	Normal Cognitive Function	Fluid Intelligence Impairment	Cognitive Impairment
Prevalence of Latent Status:			
Time 1 (2010)	87.90%	10.30%	1.80%
Time 2 (2012)	82.89%	15.00%	2.11%
Time 3 (2014)	79.03%	17.56%	3.41%

Table 4
Transition probabilities for the latent profile transition analysis model.

	Time 2(2012)		
	Normal Cognitive Function	Fluid Intelligence Impairment	Cognitive Impairment
Time 1(2010)			
Normal Cognitive Function	**0.22**	0.47	0.30
Fluid Intelligence Impairment	0.07	**0.72**	0.22
Cognitive Impairment	0.00	0.01	**0.99**
Time 3(2014)			
Normal Cognitive Function	**0.34**	0.34	0.32
Fluid Intelligence Impairment	0.07	**0.62**	0.31
Cognitive Impairment	0.00	0.00	**1.00**

Transition probabilities in bold font correspond to membership in the same latent status at each wave.

Table 5
Logistic regression coefficients for the LPTA model with age, gender, levels of education and nursing home covariates.

	Covariates	Logistic regression coefficients	*SEs*	*z*-values	*p*-values	Odds ratio
Time 1 (2010)						
Fluid Intelligence Impairment	Age	1.49	0.13	125.25	< 0.001	0.23
	Gender	0.36	0.15	6.16	< 0.05	1.44
	Levels of education	0.66	0.10	39.72	< 0.001	1.93
	Nursing home	–	–	–	–	–
Cognitive Impairment	Age	1.52	0.25	37.90	< 0.001	0.22
	Gender	0.47	0.27	3.06	0.08	1.59
	Levels of education	−0.48	0.15	10.22	< 0.001	0.62
	Nursing home	−1.79	1.02	3.09	0.08	0.17
Time 2 (2012)						
Fluid Intelligence Impairment	Age	1.79	0.16	129.61	< 0.001	0.17
	Gender	0.62	0.16	15.09	< 0.001	1.86
	Levels of education	0.82	0.12	48.48	< 0.001	2.28
	Nursing home	−3.01	1.01	8.85	< 0.01	0.05
Cognitive Impairment	Age	1.40	0.31	20.85	< 0.001	0.25
	Gender	−0.20	0.31	0.41	0.52	0.82
	Levels of education	−0.43	0.18	5.70	< 0.05	0.65
	Nursing home	–	–	–	–	–
Time 3 (2014)						
Fluid Intelligence Impairment	Age	1.73	0.18	88.49	< 0.001	0.18
	Gender	0.67	0.18	13.65	< 0.001	1.95
	Levels of education	0.64	0.13	24.96	< 0.001	1.90
	Nursing home	−2.54	1.01	6.28	< 0.05	0.08
Cognitive Impairment	Age	1.59	0.36	19.48	< 0.001	0.20
	Gender	0.32	0.35	0.85	0.36	1.37
	Levels of education	−0.24	0.20	1.35	0.25	0.79
	Nursing home	–	–	–	–	–

- The results were not convergent.

latent status, individuals who were older (1.73, $p < .001$; 1.59, $p < .001$) were more likely to be in *Fluid Intelligence Impairment* latent status and *Cognitive Impairment* latent status. Likewise, individuals who had higher levels of education were more likely to be in *Fluid Intelligence Impairment* latent status (0.64, $p < .001$). And participants who were female (0.67, $p < .001$) had an increase in the odds of being in the *Fluid Intelligence Impairment* profile compared with the *Normal Cognitive Function* profile. Nevertheless, older adults with nursing home were less likely to be in the *Fluid Intelligence Impairment* profile compared with the *Normal Cognitive Function* profile.

4. Discussion

Results of the present study identified three subtypes (*Normal cognitive function*; *Fluid Intelligence Impairment*; *Cognitive Impairment*) characterizing cognitive function among older adults over a 4-year period. The LPA and LPTA demonstrated a good fit to these data, suggesting high posterior probabilities within subtype. The first class, *Normal Cognitive Function*, had high scores of all TICS measures. The second class, *Cognitive Impairment*, had low scores of all TICS measures. The third class, *Fluid Intelligence Impairment*, showed low scores of the measure of backward counting from 20 and moderate scores of the other TICS measures. Prior research generally confirms that the TICS is designed to assess the most basic level of cognitive function, including a memory factor, consisting of the immediate and delayed recall tasks, and a mental status factor, consisting of serial seven subtraction, backwards count from 20 and naming (Albert, 1994; Ofstedal, Fisher, & Herzog, 2005). Moreover, researchers have shown that the individual items can be mapped on the cognitive dimensions. For example, counting backwards reflects the cognitive abilities of fluid intelligence or process, and object identification reflects the cognitive abilities of crystallized intelligence or product (Rodgers et al., 2003). The classification we found in our study revealed heterogeneity among these older adults in our sample (see Figs. 1–3). Individuals from the *Fluid Intelligence Impairment* profile indicated that a major factor contributing to cognitive decline is the substantial declines in fluid intelligence. Older adults from the *Cognitive Impairment* profile showed dramatic deterioration in cognitive abilities including immediate memory, delayed memory, working memory, fluid intelligence and crystallized intelligence.

This study indicated that the transition patterns in this population were remarkably stable over time (see Table 4). In particular over 60% of the population labeled *Fluid Intelligence Impairment* and *Cognitive Impairment* remained in the primary status over four years. Additionally, older adults in the *Normal Cognitive Function* latent profile were at risk of transitioning to the much worse cognitive function profiles over time. As a result of the transition probabilities we found in our study, over 30% of older adults converted from the *Normal Cognitive Function* to the *Fluid Intelligence Impairment* or *Cognitive Impairment*, and over 20% of older adults converted from the *Fluid Intelligence Impairment* to the *Cognitive Impairment*, indicating a decline in cognitive function. Previous studies have proven that gradual cognitive decline is common in late life (Lamar, Resnick, & Zonderman, 2003; Park et al., 1996; Salthouse, 2001; Schaie, 1993; Zelinski & Stewart, 1998). A 3 years population-based study of older adults in the Netherlands revealed that 18.2% of them showed cognitive decline over years, and 44% of this group stayed stable in the next 3 years (Comijs, Dik, Deeg, & Jonker, 2004). Following the practice of the HRS and the Assets and Health Dynamics of the Oldest Old (AHEAD) investigators, a cut off score of eight or less on the TICS summary measure indicates the presence of moderate to severe cognitive impairment (Herzog & Wallace, 1997). However, cognitive decline is a major health problem of older people. What if someone's score was higher than eight, meanwhile showing cognitive decline? Diagnosis by the total score would lead to a potential risk. *Fluid Intelligence Impairment* is the transitional phase between *Normal Cognitive Function* and *Cognitive Impairment*, characterized by substantial declines in crystallized intelligence. For the 22% and 31% of the population labeled *Fluid Intelligence Impairment* converted to *Cognitive Impairment* status over four years, family members should take care of these individuals and be vigilant for the deterioration in crystallized intelligence. Besides, older adults from the *Cognitive Impairment* profile showed dramatic deterioration in cognitive abilities and over 99% of the population remained in the primary status over four years. That is, for the older adults labeled *Cognitive Impairment* would be at high risk of subsequent dementia. Clinically, we need to take action against dementia, and focus on prevention and disease-modifying therapies. This study revealed that diagnosis by the total score would not be useful to design tailored interventions in preventing or retarding the development of cognitive decline among older adults. Thus, the identification of heterogeneous subtypes provides an opportunity for researchers examining the efficacy of prevention and intervention strategies targeted to specific cognitive function profiles.

It is clear that cognitive decline diminishes the quality of life of older adults, so the prevention and treatment of cognitive decline is of primary importance to older people. However, the rate of cognitive decline varies substantially among older individuals in the population (Comijs et al., 2004; Schaie, 1993; Zelinski & Stewart, 1998). To our knowledge, it is the first study to explore demographic characteristics associated with specific subtypes of cognitive function among older adults. As one grows older, cognitive impairment is one of the major causes of disability, which can result in an inability to care for oneself (Suthers et al., 2003). Consistent with previous studies, age was associated with older adults' cognitive function, which might be at higher risk of subsequent cognitive decline (Crimmins et al., 2011, Boot et al., 2013; McArdle et al., 2007; Stephan et al., 2016; Suthers et al., 2003). Further, we found that women were at higher risk of lower cognitive function than men. Previous studies had demonstrated that women in the United States experienced cognitive impairment for a greater number of years because of longer lives (Ofstedal et al., 1999; Suthers et al., 2003). The longitudinal analysis showed that older adults who had higher educational levels increased the odds of being in the *Fluid Intelligence Impairment* profile compared with the *Normal Cognitive Function*. In contrast, older adults who had lower education levels decreased the odds of being in the *Cognitive Impairment* profile compared with the *Normal Cognitive Function*, indicating that lower levels of education were associated with a great risk of poor cognitive performance, but higher education did not protect against cognitive decline. Several evidences showed the inconsistency that education influenced cognitive stability and decline (Ardila et al., 2000; Cagney & Lauderdale, 2002; Colsher & Wallace, 1991; Lee, Kawachi, Berkman, & Grodstein, 2003; Lièvre et al., 2008; Ofstedal et al., 1999). Besides, our results were consistent with previous literature showing older adults with nursing home were less likely to bear a burden of cognitive decline (Clark et al., 2013). In Summary, increasing age was a significant factor of the increased likelihood of cognitive decline. Female, individuals with no nursing home and lower educational level might be at higher risk of subsequent cognitive decline, but these factors did not play an important role in the cognitive impairment profile. In the light of the current findings, this study highlighted the usefulness to adopt a person-centered approach (assessment of cognitive function profiles) rather than a variable-centered approach. The person-centered approach might be useful in identifying higher risk profiles for individuals with particular characteristics in need of adaptive intervention approaches (Collins, Murphy, & Bierman, 2004). Further, the overarching goal of this study was to determine profiles of cognitive function in older adults, which not only better helped to improve diagnostic practices but would inform clinical management of designing targeted interventions aimed to improve cognitive function in these older adults.

This study identified subtypes and transition patterns specific to cognitive function among American older adults in a large-scale national survey. However, as is always the case with the latent profile transition analysis studies, the cognitive function profiles are data driven and sample specific (Martinent & Decret, 2015; Martinent & Nicolas, 2016), results may not generalize to other groups. Longitudinal studies on cognitive function of more diverse cohorts are needed. Another methodological limitation refers to the model selection in LPA and LPTA, which is a significant challenge in all mixture models (Ni et al., 2017). Therefore, more research on statistical power in LPA and LPTA is warranted. Furthermore, in the present study, it is inappropriate to make causal inferences (e.g., the relationship between the cognitive function and the education levels). Future research on longer period of observation would improve the ability to characterize the relationship between cognitive function and baseline demographic features.

In summary, this study demonstrated a person-centered approach in a large-scale national survey of cognitive function among older adults in America, which might provide researchers with a useful way to explore cognitive function profiles and the stability or change of these profiles over time. Differential bivariate relationships were found between cognitive function and selected relevant variables, these findings highlighted the importance of age, gender, levels of education and nursing home as predicting factors in cognitive function among older adults. This study was in support of adopting a person-centered approach rather than a variable-centered approach, suggesting directions for future research and tailored interventions in improving cognitive function among older adults with particular characteristics.

Conflict of interest

None to declare.

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