Association between declarative memory and language ability in older Chinese by education level

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Abstract

Episodic memory and semantic memory are two subsystems of declarative memory which is considered to be related to language ability. We investigated the interdependence of the episodic and semantic memory and their association with syntactic complexity in two groups of Chinese older adults with higher and lower education levels. The results indicate that episodic memory and semantic memory are significantly correlated with each other, but only episodic memory shows a significant relationship with syntactic complexity. Educational attainment has a substantial influence on the performance of memory tasks, but no influence on the syntactic complexity. The study provides new evidence from Chinese older adults for clarifying the association between declarative memory and syntactic processing and the benefits from education on memory preservation in later life.

1 Introduction

Nowadays, China is facing an aging population. According to the general definition of an aging society published by the United Nations in 1956[1], when a country or region's population aged 65 and above accounts for 7% of the total population, the country or region enters the aged stage. China has around 88 million elderly people aged 65 and above as early as 2000, accounting for 7% of the total population, which means that China officially entered the aging society two decades ago. For the past over ten years, according to the National Bureau of Statistics of China[2], this number has continued to climb and exceeded 160 million by the latest 2018, which has nearly doubled from 2000 and occupied 11.9% of the entire population. Previous studies suggested that older adults are vulnerable to memory decline (for a review, see Buckner, 2004) and language attrition (for a review, see Burke and Shafto, 2011). However, since most of these studies have been based on the WEIRD population (Henrich et al., 2010a; Henrich et al., 2010b), it remains to be established what changes

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[1] Department of Economic and Social Affairs, United Nations, *The Aging of Populations and Its Economic and Social Implications* (New York: United Nations, 1956), 7.
[2] For details, see http://data.stats.gov.cn/easyquery.htm?cn=C01&zb=A0305&sj=2017.

Chinese older adults undergo in terms of memory ability and language usage, and how memory ability and language usage interact with each other in older Chinese.

1.1 Declarative and Procedure Model

Memory is not a single process but has at least two major forms, namely, declarative memory and procedure memory which are both associated with language ability, as proposed in the declarative and procedure model. (Ullman, 2001a, 2001b, 2004). Declarative memory is an explicit and conscious recollection of arbitrarily related information, such as the people, places, and objects in specific events and the general knowledge about facts. On the contrary, procedure memory functions implicitly and unconsciously, in which habits and skills are computed automatically. In terms of language usage, the declarative memory serves the mental lexicon of memorization of the word-specific knowledge, whereas the procedure memory assists the mental grammar of the rule-governed complex representations. Besides, with regard to anatomical structures, long-term storage of procedure memory involves in the frontal cortex and basal ganglia circuits, especially the striatum, while long-term storage of declarative memory requires the hippocampus and the medial temporal lobe of the neocortex which also subserve language processing (Piai et al., 2016; Ullman, 2014).

Declarative memory and procedure memory alter in different trajectories across the lifespan (for a review, see Hedden and Gabrieli, 2004). The procedure memory barely exhibits age-related declines, whereas declarative memory, particularly encoding new memories of episodes or facts, declines evidently in the late years. A piece of robust evidence is that the preliminary phases of Alzheimer's disease are hallmarked by shortfalls in declarative memory, for instance, the older adults are only able to store fewer number of objects or specific events than the younger adults for a long period of time (Buckner, 2004; Lai and Lin, 2013). Besides, brain regional changes in volume are not uniform pertaining to declarative memory and procedure memory. Striatal volume declines by about 3% per decade at a span between 20 and 80 years of age (Gunning-Dixon et al., 1998), whereas hippocampus and the parahippocampal gyrus shows a 2–3% per decade decline in the volume (Raz et al., 2004), and might extend to a 1% per annual decline after the age of 70 (Jack et al., 1998), which would likely deteriorate the neural mechanical foundation of declarative memory and related language ability.

What's more, regarding the function in language processing, declarative memory and procedure memory implicate different alterations in older adults. Kempler et al. (1987) demonstrated that syntactic processing and semantic processing are separately operating in patients with Alzheimer's disease. They required subjects to perform spontaneous speech tasks and write to dictation tasks, and analyzed their syntactic complexity and errors, as well as semantic errors. Eventually, they found that compared to the semantic ability which is likely linked to the declarative memory, the syntactic ability is selectively conserved due to its automatic nature which is related to the procedure memory. The syntactic ability seems to remain intact in the late years of life, but it lacks close inspections in the Chinese population.

In addition to the distinct functions of declarative memory and procedure memory, it is noted that they could also cross the boundary in language processing (Ullman, 2014). Complex structures, such as "walked" can be an example to illustrate this point. In procedure memory, "walked" could be computed into the composition of the original word "walk" and English regular past tense "-ed", which can be stored based on its rule-based grammatic foundation. However, it could also be acquired and stored as a chunk in the declarative memory. This is the so-called compensatory role of declarative memory to procedure memory (Ullman et al., 2020; Ullman and Pierpont, 2005), which is widely found in patients with neurodevelopmental disorders (Evans and Ullman, 2016; Lee et al., 2020; Lum et al., 2012; Ullman and Pullman, 2015; Walenski et al., 2014), but scarcely investigated in the aging population (Rieckmann and Bäckman, 2009). In the current research, we aimed to investigate whether and how declarative memory associates with the rule-based syntactic process, especially the syntactic complexity in Chinese older adults via delving into its two component subcategories, namely episodic memory and semantic memory as described below.

1.2 Episodic Memory and Semantic Memory

Declarative memory can be divided into episodic memory and semantic memory (Greenberg and Verfaellie, 2010; Tulving, 1972). Episodic memory refers to the collection of specific events or experiences which entails the personal realization of what was happening and can be reconstructed vividly with many details from the individuals' perspective (Garrard et al., 1997). That is to say, episodic memory includes the exact contextual information, such as times, locations, persons, and related feelings, and most individuals regard themselves as the actors or contemporary witnesses in these autobiographic events. Therefore, episodic memory involves the emotional charge and the whole context surrounding an occurrence, rather than the bare facts of the occurrence itself. By contrast, semantic memory is a more structured record and embraces the recollection of general information of facts and concepts about the external world which shares with others and involves no personal emotional charge (Squire and Zola, 1998). Much of semantic memory is abstract and is connected with the meaning of verbal symbols.

The story recall task is considered as a common method to assess the episodic memory (Baudic et al., 2006; De Anna et al., 2008; Hertzog et al., 2003), whereas the verbal fluency task has been widely used to test the semantic memory (Chertkow and Bub, 1990; Henry et al., 2004). Moreover, Kavé and Sapir-Yogev (2020) put forward shared mechanisms for both delayed retrieval of story information on story recall tasks and retrieval of words on verbal fluency tasks, which also functioned in the older adults. They asked subjects to complete tasks of verbal fluency and recollect the story that they heard after a delay of around 30 min. The results showed that there are significant correlations between semantic fluency and delayed story recall, and the delayed story recall significantly contributes to semantic fluency performance when conducting the regression analysis. Episodic and semantic memory seems to be interdependent and affect each other both at encoding and at retrieval (Greenberg and Verfaellie, 2010), but this is less examined in the Chinese population.

Furthermore, recent neural research exhibits that hippocampal theta oscillations are discovered during online language processing in addition to memory function, which suggests that the hippocampal complex contributes to a shared neurophysiological mechanism between language and episodic memory (Piai et al., 2016; Pu et al., 2020). However, it remains unclear whether and how episodic memory and semantic memory interact with language usage, and in the present study, we aimed to elucidate the association between episodic memory and syntactic complexity, and the relationship between semantic memory and syntactic complexity as well.

1.3 Education Effects

Although all humans cannot escape from aging, the trajectories of both their memory decline and language attrition proceed dissimilarly in which education plays an important role. Anatomically, education has a profound influence on the aging of specific hippocampal subfields, for instance, there are significant negative correlations between educational attainment and the atrophy of hippocampal CA2/3 in older men (Jiang et al., 2019). On the other hand, education appears to have positive effects on declarative memory in older adults (Reifegerste et al., 2020). For instance, when performing retention, recall, and recognition tasks in word memory tests, less educated healthy older adults showed significantly decreased scores and lower response rates in all tests, compared to the higher-educated equivalents (de Azeredo Passos et al., 2015). This also happened in patients with Alzheimer's disease that those attained lower education levels obtained fewer scores of recall tasks in the mini-mental state examination test (MMSE) (Delpak and Talebi, 2020). And language ability is one of the most impaired domains for these patients with low education level in the above MMSE test. Besides, educational attainment is also associated with semantic memory (Gladsjo et al., 1999) and episodic memory (Zahodne et al., 2019) among non-Chinese speaking older adults.

However, it is still unclear whether a higher education level is a protective factor against age-related memory decline and language attrition for the Chinese population, and how educational attainment affects the trajectories of memory decline and language attrition in Chinese older adults due to the scarce research. Therefore, the current study aimed to seek whether and how Chinese older adults with higher and lower

education levels perform differently on memory processing and language usage.

1.4 The Present Study

The current study investigated whether the language ability of Chinese older adults, especially the ability of syntactic processing, is affected by declarative memory, or put it in another way, by the episodic memory and semantic memory. In order to answer this question, delayed story recall tasks and verbal fluency tasks were utilized. Moreover, we also explored whether the performance of delayed story recall is related to verbal fluency on Chinese older adults, since both episodic memory and semantic memory belong to declarative memory. Besides, educational attainment was designed as a controlling factor in order to explore whether and how education level impacts the memory decline and language attrition on Chinese older adults.

2 Methods

2.1 Participants

We recruited 36 participants, of whom eighteen are from Shenzhen (SZ participants) and speak Mandarin daily. The other eighteen participants were recruited in Chenzhou (CZ participants), and speak Chenzhou dialect[3] in daily life. There were 6 males and 12 females in SZ cohorts, and 11 males and 7 females in CZ cohorts. SZ participants and CZ participants were matched on age, but differed in education level. The SZ participants varied in age from 61 to 74 years with an average age of 66.0 ± 4.9 years, while CZ varied in age from 63 to 79 years with an average age of 69.4 ± 4.4 years. There was no statistically significant difference between SZ and CZ participants on age ($t = -1.637$, $p = .119$). By contrast, the SZ participants varied from 15 to 21 years with a mean of 16.3 ± 1.8 years on the level of education, and the CZ participants varied from 2 to 11 years with a mean of 7 ± 2.8 years on the educational attainment. There was a statistically significant difference between SZ and CZ participants on the level of education ($t = 8.9078$, $p < .001$). Besides,

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[3] Chenzhou dialect is subordinate to Southeastern dialect, which is similar to Mandarin Chinese in syntax (Shan 单泽周, 1997).

for both two groups of participants, if they had a past history of brain traumatic injury, stroke, clinical depression, alcoholism, and vision and hearing problems, they were not included in the study. The experiments were approved by The Hong Kong Polytechnic University's Human Subject Ethics Subcommittee. Prior informed consent was obtained from all participants.

2.2 Psycholinguistic Measures

Story Recall: The delayed story recall is an efficient assessment for episodic memory, and it is also included in the frequently uesd Wechsler Memory Scale-Fourth Edition of Chinese version (adult battery)[4]. In that battery, subjects are required to recollect the story that the experimenter read for them. That is to say, subjects might mimic the sentences and syntactic structures that the experimenter used. However, in the current study, the syntactic ability is what we plan to survey. Thus, recalling a written story is not suitable to inspect participants' syntactic ability. Instead, we asked participants to watch a six-minute movie of pear story and then verbalize what they have remembered, which requires subjects to create their own speech production to describe the story, rather than simply recall the sentences appeared in the story essay. In this way, the subjects' language usage and memory ability can be measured at the same time.

The six-minute movie is developed by Wallace Chafe in 1975, and it shows a farmer harvests pears in the morning, and a boy who passes on a bike steals a basket of pears. And then the boy experiences falling from the bike and getting help from other children, before the farmer finds he loses some pears (Chafe, 1980). After subjects finished watching the movie, they were asked to recall the story immediately. And after 30 minutes, they were asked to recall the story again. The syntactic complexity of their speech production and the number of information units they recalled were analyzed in both immediate recall and delayed recall.

Verbal Fluency: Verbal fluency tasks were applied to measure participants' semantic memory (Kavé and Sapir-Yogev, 2020), in which participants were asked to produce as many words as possible within one minute on one semantic

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[4] Refer to Wang 王健 et al. (2015) for more details.

category. There were four different semantic categories, namely, fruit, tool, Chinese city, and profession. The first two categories belong to the concrete domain, while the latter two categories belong to the abstract domain. The total number of items of four categories was counted, and the unrelated and repeated words were excluded.

2.3 Procedure

Participants first provided their basic demographic information, including their age, language experience and education level, and then finished the Montreal Cognitive Assessment test (Nasreddine et al., 2005) which implies their mental states. Then participants began to watch the pear story film and immediately verbalized what they had remembered. After around 30 minutes, they were asked to complete the delayed recall tasks. During the interval, participants worked on some other nonverbal cognitive tests to distract their attention from the story recall task. Afterward, participants started to complete the verbal fluency tasks. The whole testing session lasted around 1 hour. Participants completed all tasks with an experimenter individually and had a rest when feeling tired.

2.4 Data Analysis

Information Unit: Information unit is an index to measure the participants' episodic memory, which involves "actors, activities, objects, numbers, days, times, or places" (Kavé and Sapir-Yogev, 2020), and there are 79 information units in total in the pear story film[5]. Participants' recalled stories were transcribed verbatim, and all information units were screened based on the uniform standard. At last, five types of information units were obtained, which are valid information unit, missing information unit, mismatch information unit, unrelated information unit and wrong information unit, and they have different states in scoring, as shown in appendix A of the data from one participant.

The first type is the valid information unit that correctly describes the sceneries in the pear story film. For instance, the participant recollected the information unit that the rooster crowed both in immediate recall and delayed recall, so the

participant can obtain 1 score both in immediate recall and delayed recall[6]. The second type is the missing information unit which is the plot that the participant failed to mention in both immediate recall and delayed recall. For example, in both immediate recall and delayed recall, the participant missed the information unit of two baskets of pears which is quite an important clue, so in both of them, the participant obtained 0 scores.

The third and fourth situations in appendix A demonstrate the mismatch information unit which means the participant recollected the sceneries correctly only in one version of recall or missed the plots in one recall task, so only the recall task that the participant succeeded to evoke and describe accurately can obtain 1 score. In the third situation, the participant recollected the information unit that the boy who takes pears turns his head back in the immediate recall but missed it in the delayed recall, so this participant obtained 1 scores in the immediate recall but 0 score in delayed recall. On the contrary, in the fourth situation, the participant retrieved the information unit of how the boy left only in the delayed recall but failed to recall this information unit in the immediate recall and replaced it with the unrelated information unit of saying thank you. The last two types are the unrelated information unit and the wrong information unit, and both of them obtain 0 scores, since both of them reflect that the participants formed nonsensical episodic memory. For instance, the participant utilized unrelated information unit of saying thanks and wrong information unit of riding the bike to mistakenly substitute the correct information unit of pushing the bike.

Syntactic Complexity: In order to assess the syntactic ability of the participants, the syntactic complexity of speech production from the story recall task was analyzed. After meticulously transcribing all the speech utterances, 20 sentences were selected for each participant, in which 10 sentences were chosen from the immediate recall task and the other 10 sentences were chose from the delay recall task and both of them were scanned and selected from the beginning of the

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[5] The participants' recall data were taken into consideration when counting the total information units of the pear story.

[6] Actually, the participant can obtain 2 scores for both immediate recall and delayed recall, as he mentioned the information unit of one morning in the countryside. Here we marked one score for simplistic demonstration and applied the same way on the following illustration.

recall production. We selected these 20 sentences, rather than all sentences, in order to make sure that the same number of sentences were finally obtained to be analyzed, since participants produced inequable number of sentences in their recalls. Furthermore, incomprehensible sentences were excluded, such as sentences with fatal syntactic or semantic errors. Before performing syntactic analysis on these transcribed sentences, the redundant elements, such as phonetic error, filler, and nonsense repetition, were deleted from the original sentences, as shown in the below.

Original sentence:

呃	那个	果农	摘	梨	的	那个
filler	that	farmer	pick	pear	auxiliary word	that
[s]	那个	那个	方法	挺	有意思	。
phonetic error	repetition	repetition	method	quite	interesting	.

Refined sentence:

那个	果农	摘	梨	的	那个
that	farmer	pick	pear	auxiliary word	that
方法	挺	有意思			。
method	quite	interesting			.

Translation:
The method that the farmer applies is quite interesting.

After dispelling the redundant elements in the original sentence, we obtained the refined sentence to conduct syntactic complexity analysis. According to Chao (1968)'s theory, there are five syntactic types of smaller constructions within one sentence, which are coordination, subordination, verb-objection(V-O) construction, verbal expressions in series, verb-complement(V-R) construction. These basic syntactic constructions can be "iterated and/or combined" to generate a more complicated structure. Based on these criteria, in the above example, 那个果农, 那个方法, 摘梨的那个方法 and 挺有意思 are four subordinations, and 摘梨 is a V-O construction, and eventually, this sentence contains five syntactic constructions and scores 5 points in total.

Speech Rate: In addition to the syntactic complexity, we also analyzed the speech rate of speech production in story recall tasks. Speech rate reflects how fast the participants speak and it is positively related to the number of sinograms and negatively related to the duration of their speech production. We firstly assessed the total number of sinograms the participants produced in both immediate recall and delayed recall and how much time they spent, and then calculated the speech rate by dividing the total number of sinograms by the total duration.

Information unit analysis and syntactic complexity analysis were performed by one trained rater who is a native speaker of both Mandarin and Chenzhou dialect. All statistical analyses were conducted by R program language.

3 Results

3.1 Performance Comparison between Two Groups

Firstly, we calculated the mean scores of SZ and CZ participants' performance in all tasks, as shown in table 1.

Group	Verbal Fluency	Duration(S)	Sinograms	Speech Rate	Immediate Recall	Delayed Recall	Syntactic Complexity
SZ	65.4	199.4	814	4.1	28.4	30.8	5.72
CZ	38.6	52.6	204	3.9	14.9	12.8	5.26

Table 1. Average scores of SZ and CZ participants

Through independent t-test, we found that there were significant differences between SZ and CZ participants in verbal fluency performance ($t = 7.0224$, $p < .001$), duration of story recall ($t = 4.535$, $p < .001$), the number of sinograms in story recall ($t = 3.778$, $p = .003$), the number of information units in immediate recall ($t = 4.421$, $p < .001$), and the number of information units in delayed recall ($t = 5.895$, $p < .001$). In contrast, no significant difference was found between these two groups in speech rate of story recall ($t = 0.791$, $p < .441$) and syntactic complexity ($t = 1.255$, $p = .2264$). That is to say, education level would affect subjects' results of verbal fluency tasks and delayed recall tasks but have limited influence on the speech production pertaining to the speech rate and syntactic complexity of their utterances.

3.2 Correlation Analysis

In order to examine the association between semantic memory and episodic memory, we conducted a correlation analysis on the results of verbal fluency tasks and story recall tasks. Also, to examine the relationship between syntactic processing and declarative memory, and the role of educational attainment, we added syntactic complexity and education years in the correlation analysis, as shown in table 2.

Task	Verbal fluency		Syntactic complexity		Education years	
	r	p	r	p	r	p
Immediate recall	0.82 9	< . 001 ***	0.57 7	0.00 8 **	0.78 8	< . 001 ***
Delayed recall	0.84 7	< . 001 ***	0.49 8	0.02 5 *	0.83 6	< . 001 ***
Verbal fluency	-	-	0.38 2	0.09 7	0.86 3	< . 001 ***
Syntactic complexity	0.38 2	0.0 97	-	-	0.36 9	0.10 9

* p < .05; ** p < .01; *** p < .0001.

Table 2. Correlations between verbal fluency tasks and story recall tasks

It is noted that verbal fluency performance has a significant strong positive correlation with the numbers of information units in both immediate recall and delayed recall, but not significantly related to syntactic complexity. However, syntactic complexity is significantly correlated with the numbers of information units in both immediate recall and delayed recall, which shows a moderate positive corelation. Besides, education level has a significant strong positive correlation with the verbal fluency performance and the numbers of information units in both immediate recall and delayed recall, but is not significantly related with syntactic complexity (r = 0.369, p = .1094), as mentioned in the table 1 before that SZ participants and CZ participants show no significant difference in syntactic complexity.

3.3 Regression Model of Syntactic Complexity

In order to further explore the association between episodic memory and syntactic processing, a simple linear regression was run to predict participants' syntactic complexity based on their information units recollected in delayed recall[7], as shown in the table 3.

	β	SE	t	p	R^2
Intercept	4.696	.366	12.841	< .001***	.2479
Delayed Recall	.036	.015	2.436	.0255*	

* p < .05; ** p < .01; *** p < .0001.

Table 3. linear regression predicting syntactic complexity

It is obvious that a significant regression equation was found (F (1, 34) = 5.932, p = .02549), with an R^2 of 0.2479. Participants' predicted syntactic complexity is equal to 4.696 +0.036 (information units). Participants' average syntactic complexity increased by 0.036 for each information unit, which means the information unit can significantly predict the variation of syntactic complexity of speech production in Chinese older adults.

4 Discussion

Our results show significant associations between performance on the verbal fluency tasks and the delayed story recall tasks, which is consistent with the results of previous studies (Kavé and Sapir-Yogev, 2020). Verbal fluency tasks and delayed story recall tasks are two measurements reflecting semantic memory and episodic memory respectively. As both semantic memory and episodic memory are subordinate to declarative memory (Squire and Zola, 1998; Tulving and Schacter, 1990), and both of them vary along a continuum of processing and stored by the similar brain regions (Rajah and McIntosh, 2005), it is not surprising that they are correlated with each other. Besides, episodic memory can convert into semantic memory after accumulated repetition (Garrard et al., 1997), which also underlines their connection.

Previous studies have demonstrated that declarative memory is considered to be less connected to syntactic processing (Ullman, 2001a, 2001b, 2004, 2013, 2014, 2016), which is

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[7] The independent factor of the results of the immediate recall was excluded, because it is partly confounded with the status of working memory (Reifegerste et al., 2020).

consistent with the results of semantic memory performance but inconsistent with the results of episodic memory performance in the current study, as the number of information units in delayed recall contributes to the prediction of the syntactic complexity in online speech production, but dissociates from the number of generating words in verbal fluency tasks. This is probably because most previous studies focus on syntactic correctness judgment, which is, to some extent, distinct from online speech production in the present study. For instance, Pu et al. (2020) found that hippocampal theta power which is connected with episodic memory specifically associates with semantic errors rather than syntactic errors in perception modal. Indeed, readers might ignore the syntactic incorrectness in a sentence in order to obtain the whole meaning of the sentence, but it seems not to prove that they are not able to produce syntactically complicated natural sentences in language tasks. Another point is that even though declarative memory plays a compensatory role to procedure memory in syntactic processing (Ullman et al., 2020; Ullman and Pierpont, 2005), it appears to be only applied to the episodic memory. It needs more meticulous studies to untangle the complicated relationship between episodic and semantic memory and syntactic ability.

Another interesting phenomenon is that SZ participants and CZ participants showed no significant differences in syntactic complexity in the story recall utterances, although they have significant differences in education level. That is to say, educational attainment does not affect speakers' syntactic manipulation in speech production. Language enables its users to exploit syntactic processing equally, and syntactic ability keeps intact from other external factors. However, it does not mean all speakers can take full advantage of this ability to complete relevant tasks perfectly. Previous studies in Chinese adults have claimed that different educational attainments would lead to different patterns of neural activation associated with language tasks (Li et al., 2006), and different results in verbal fluency tasks (Mok et al., 2004). In verbal fluency tasks, CZ participants who attained lower education levels generated significantly fewer items than SZ participants. Low-educated participants appear to experience semantic memory deficits (Yang et al., 2006). Besides, in story recall tasks, SZ participants verbalized longer descriptions and more sinograms in their recall than CZ participants, as CZ participants sometimes failed to articulate some plots in recall and caused fewer number of sinograms. Even though both two groups had similar syntactic complexity in their utterance, they performed differently in language tasks due to their disparate educational attainments. It suggests that education plays an important role in moderating the weakness of age-related cognitive decline, especially memory decline. The limitations of this study was the wide range of age for both groups as memory loss is vulnerable to age differences, and that we did not correlate language and memory performance with their occupations as different professions involve in different magnitude of cognitive activities and affect their performance.

5 Conclusion

The current study recruited two groups of Chinese older adults with different education levels to perform verbal fluency tasks and story recall tasks in order to investigate the association between declarative memory and language usage. The results show that verbal fluency performance is significantly related to the number of recollected information units in both immediate recall and delayed recall, which suggests that the two subcategories, semantic memory, and episodic memory are closely connected with each other. However, only episodic memory shows a significant association with syntactic complexity in the story recall utterances. Furthermore, education level plays a large role in verbal fluency tasks and story recall tasks for Chinese older adults, but has little influence on the syntactic complexity of their online speech production. Higher educational attainment appears to yield considerable benefits to the resistance of age-related declarative memory decline for Chinese older adults.

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Appendices

Appendix A. Five types of information unit

Immediate recall	Delay recall	Type	Scores
一个农村的早上，鸡叫了。 [8] One morning in the countryside, the rooster crowed.	一个农村的清晨，鸡叫了，天亮了。 One morning in the countryside, the rooster crowed and it dawned.	Valid information unit	Immediate recall: 1 Delay recall: 1
Two baskets of pears have been collected.	Two baskets of pears have been collected.	Missing information unit	Immediate recall: 0 Delay recall: 0
打了一个口哨。他回过头来，他又……，这个男孩子呢，就把草帽呢，送给他，给他送过去。 Whistled. He(bicycler) looked back, and he…, this boy, uh, send the straw hat to him(bicycler), send him(bicycler) the straw hat.	然后呢就冲他吹了一下口哨。把这个草帽呢给他送过去。 Then he whistled at him(bicycler). Send him(bicycler) this straw hat.	Mismatch information unit	Immediate recall: 1 Delay recall: 0
然后，装好。他，然后就走了，也没说谢谢。 Then, pack it. He then left without saying thank you.	帮他搬在了车子上，自行车上。这个男孩子呢，骑上车呢就往前走了，推着车吧，不是骑，推着车。 Help him move it on the car, on the bike. The boy, uh, got on the bike and walked forward, pushing the bike, not riding, pushing the bike.	Mismatch information unit	Immediate recall: 0 Delay recall: 1
然后，装好。他，然后就走了，也没说谢谢。 Then, pack it. He then left without saying thank you.		Unrelated information unit	Immediate recall: 0 Delay recall: 0
他们一人拿了一个，然后就吃着走过来了。他就骑车走了。 They each took one and came over while eating. He rode away on his bike.		Wrong information unit	Immediate recall: 0 Delay recall: 0

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[8] This is the original utterance that the participant produced, and it is followed by its translation.