Production-comprehension asymmetries of semantic processing in Chinese older adults

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Introduction

Different language abilities and cognitive abilities develop and decline in different trajectories, including language production and comprehension abilities (Hartshorne, J. K., and L. T. Germine, 2015; Thornton, R. and L. L. Light, 2006). Children, at age of 16-month-old, are able to understand around 200 words but produce merely 50 words, indicating their asymmetrical production and comprehension capacities (Kuhl, P. K., & Damasio, A. R., 2013). One explanation is that their production-comprehension asymmetries are due to cognitive limitations (Hendriks, P., & Koster, C., 2010).

In spite of frequent reports of age-related language decline in the elderly, it remains unclear whether it impacts semantic production and comprehension symmetrically or asymmetrically. Besides, we also investigated how it is related to cognitive abilities, especially declarative and procedural memory systems which have been suggested to associated with semantic processing (Ullman, M. T., 2004).

Objectives

1. to investigate age-related production and comprehension changes of semantic processing in Chinese older adults;
2. to explore whether the decline in semantic production and comprehension occurs in an asymmetrical manner;
3. to examine the effects of declarative memory and procedural memory on semantic production-comprehension asymmetries.

Procedures

24 younger adults (aged 24.1±2.6 years; 12 females) and 24 older adults (aged 28.3±2.9 years; 12 females), who were both cognitively normal Chinese native speakers, were recruited for the study.

Subjects' expressive semantic abilities were evaluated through the constrained production task, where they were required to construct a sentence with two, three, or or four given words which have weak semantic relations. All stimuli were divided into three conditions based on whether they include particle Ba and whether the verb can be fitted in the Ba construction, as shown in table 1.

The correctness judgment task on Mandarin Ba construction was used to test subjects' semantic ability. The design of the stimulus is shown in Table 2. The electroencephalogram (EEG) was recorded when they were reading semantical congruent and incongruent sentences.

Declarative memory and procedural memory were measured by the declearn task and the serial reaction time task within two consecutive days (Hedenius, Ullman, Alm, Jennische, & Persson, 2013; Janacsek et al., 2020).

Table 1. Example stimuli of the constrained production task

Word combination	Suitable verb	Unsuitable verb	No particle Ba
Two-word combination	把 收拾 Ba tidy	喜欢 把 like Ba	失去 律师 lose lawyer
Three-word combination	医生 清理 把 doctor clean Ba	将军 把 听见 general Ba hear	企业家 毛巾 逃跑 entrepreneur tower escape
Four-word combination	走廊 把 警察 打破 corridor Ba police break	把 啤酒 游客 值得 Ba beer visitor worth	建立 餐厅 运动员 面具 establish canteen athlete mask

Table 2. Example stimuli of the correctness judgment task

Duration (ms)	500/1000/1500	800-1200	500	100	500	100	500	100	500	100	500	100	500	100	500	2000	
Correct sentence	ITI	+ (fixation)	园丁 Gardener	ISI	整理 trim	ISI	花园， garden,	ISI	把 Ba	ISI	杂草 weed	ISI	**拔** **pull**	ISI	了。 particle.	Response	
			The gardener pulled up the weeds when trimming the garden.														
Anomalous sentence	ITI	+ (fixation)	园丁 Gardener	ISI	整理 trim	ISI	花园， garden,	ISI	把 Ba	ISI	杂草 weed	ISI	**宰** **kill**	ISI	了。 particle.	Response	
			*The gardener killed the weeds when trimming the garden.														
Correct filler	ITI	+ (fixation)	村民 villager	ISI	办 prepare	ISI	酒席， banquet,	ISI	特地 particularly	ISI	请来 invite	ISI	**村支书** **village secretary**	ISI	了。 particle.	Response	
			Villagers prepare a banquet and particularly invite the village secretary.														
Anomalous filler	ITI	+ (fixation)	村民 villager	ISI	办 prepare	ISI	酒席， banquet,	ISI	特地 particularly	ISI	购买 buy	ISI	**村支书** **village secretary**	ISI	了。 particle.	Response	
			*Villagers prepare a banquet and particularly buy the village secretary.														

Results

Production Results:

Figure 1 illustrates the overall comparison between younger and older adults as to the total amount of time required to generate a sentence. Figures 2 and 3 show the semantic density of sentences produced in each condition and at each level by subjects. Even though there is a significant difference between younger and older adults in terms of the reaction time, older adults exhibited a similar semantic density compared to younger adults. The only exception is the condition that given words are not allowed to capture the verb position within the Ba construction, which is probably due to the additional syntactic burden rather than the semantic difficulty per se.

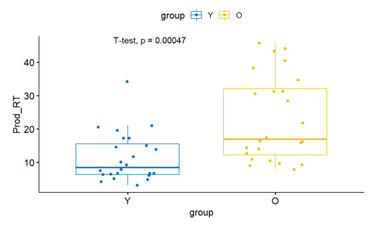

Figure 1. Overall reaction time (s) of the constrained production task

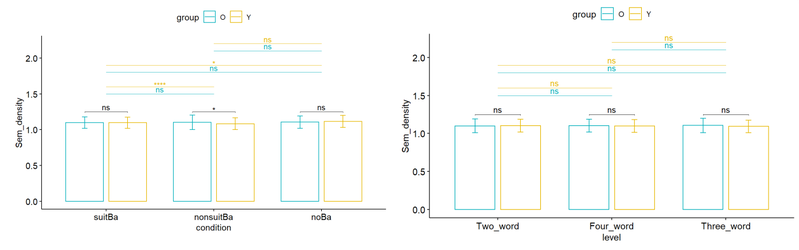

Figure 2. Semantic density across three conditions and three levels in which subjects were given with different words

Comprehension Results:

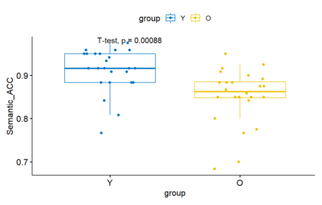

Figure 4. Accuracy rate of the correctness judgement task

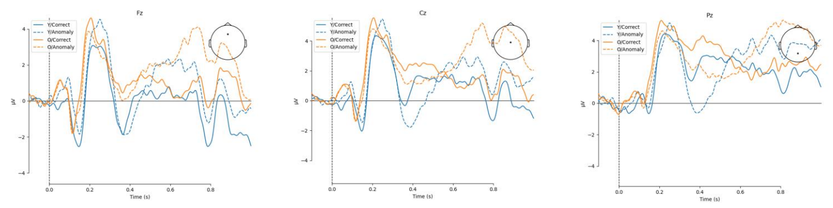

Figure 5. Younger adults' and older adults' grand average ERPs to correct and anomalous critical verbs at Fz, Cz, and Pz channels

Older adults perform significantly worse than younger adults when identifying whether a sentence is semantically correct. Regarding the neural results, there was no significant difference in the latency of the peak difference from 300 ms to 500 ms between younger (415 ms) and older (424 ms) adults, $F(1,42) = .4$, $p = .529$. Following this, mean amplitudes were measured between 320 and 520 ms and between 500 and 900 ms in order to calculate the N400 effect size and frontal positive component (FPC), respectively . They were both subjected to an omnibus ANOVA that included four factors: age group, condition, laterality, and anteriority. The main effect of group was found for both N400 ($F[1,42] = 9.55$, $p = .004$, $MSE = 50.4$) and FPC ($F[1,42] = 7$, $p = .011$, $MSE = 66.74$), but no group-related interaction was observed.

Correlation analysis Results:

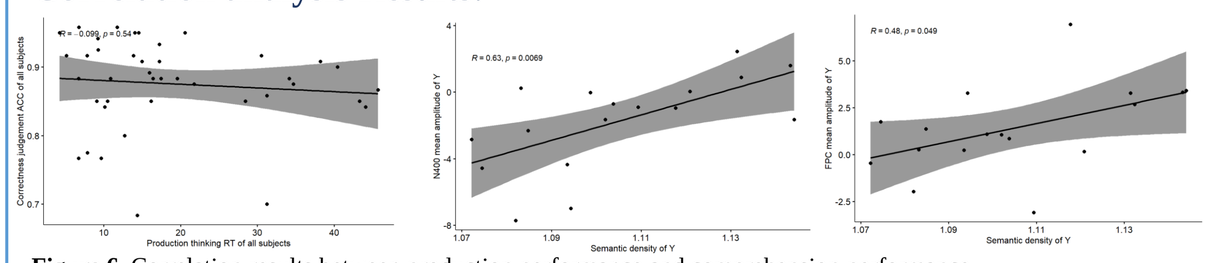

Figure 6. Correlation results between production performance and comprehension performance

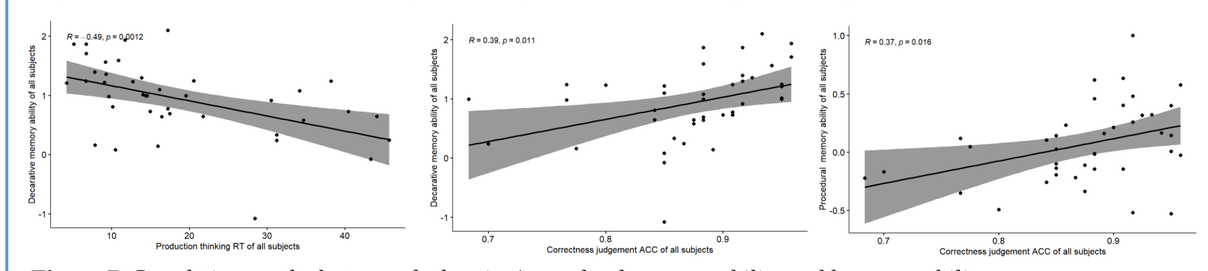

Figure 7. Correlation results between declarative/procedural memory ability and language ability

Although no positive correlations between judgment accuracy and thinking time of producing a sentence were found, suggesting no production-comprehension asymmetries on behavioral performances, subtle asymmetries already permeated through the neural domains. Only younger adults showed positive correlations between the semantic density of produced sentences and the mean amplitude of N400 and FPC.

Furthermore, a positive correlation between procedural memory and semantic processing was observed only in comprehension performance for all subjects, suggesting a divergent compensatory role of procedural memory in supporting expressive and receptive semantic processing.

Conclusions and Limitations

In conclusion, we have shown that (1) older adults performed worse than younger adults in both production tasks and comprehension tasks; (2) despite being invisible at the behavioral level, production-comprehension asymmetries of semantic processing already intruded into neural levels in older adults; (3) this potential neural-level asymmetries might be related to lifelong diverging supports of procedural memory.

The impurity of the production and comprehension tasks prevented us from revealing how far the production-comprehension asymmetries proceeded in older adults with language decline. Further research should examine the asymmetrical patterns of language production and comprehension and explore the underlying mechanisms.

Acknowledgments

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