What is the upper limit of working memory? Evidence from Chinese recursive possessive structure

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In Mandarin possessive structure ($N_{possessor}$ de $N_{possesum}$), the possessive marker DE can be dropped when the possessor bears an inalienable relationship with the possessum, as in *wo (de) mama* 'my mom'. Importantly, a possessive phrase can be nested within another possessive phrase in succession, forming possessive chains. Thus, possessive chains provide a good test case for probing into memory capacity, a factor that is known to affect real-time parsing. Existing work has yet to give a definitive answer regarding the upper limit of short-term memory capacity. While Miller (1956) posits that short-term memory capacity is "7±2", Cowan (2001) proposes that it is limited to "4±1". Using the recursive possessive chain structure in Mandarin, we set out to explore native Chinese speakers' upper limit of working memory capacity by manipulating the presence versus absence of the possessive marker "DE" between the six possessor nouns.

In **Experiment 1** (N=80), we ran a grammaticality acceptability task using a 5-point scale (1 = least acceptable, 5 = most acceptable) on *wenjuanxing* (www.wjx.cn). In the experimental stimuli, totaling 20 sets, the sentential subject consisted of 7 noun phrases (NPs), where the first NP was always the first-person pronoun *wo* 'I', followed by six inalienable kinship terms, with the 7th NP being the possessum (see ex.(1)). Between the NP2 and the NP6, we manipulated the presence or absence of "DE", yielding 5 conditions (1a-e). To prevent participants from developing test-taking strategies, we created 10 versions of tests, each having 10 experimental sentences, with 2 from each condition. In each version, 10 experimental stimuli were intermixed with20 filler sentences of various structures, and then pseudo-randomized. Fig. 1 shows participants' mean ratings by conditions. When using (c) as the baseline, we found that (a) was rated significantly higher than (c) (β= 0.32, SE = 0.15, t = 2.23, p = 0.026), and (c) was rated significantly higher than (e) (β = -0.38, SE = 0.15, t = -2.59, p = 0.0098). When using (d) as the baseline, we found (d) was rated significantly lower than (a) (β = 0.52, SE = 0.15, t = 3.66, p = 0.0003) and (b) (β = 0.31, SE = 0.15, t = 2.14, p = 0.03). But no differences were found between (c) and (d), nor between (d) and (e). These patterns suggest that starting from the 4th and 5th consecutive nouns (i.e., c & d), the acceptability gets drastically decreased.

To control potential effects of "similarity-based interference" (Gordon et al. 2006) presented in Experiment 1 due to kinship terms in a row, we ran **Experiment 2** (N=50) by alternating kinship terms with descriptive NPs (see ex.(2a-e)). We used self-paced reading with a stop-making-sense task, following Boland et al. (1989). Participants took the online test on Gorilla, followed by an offline paper-&-pen test, in which they not only rated the grammaticality of experimental sentences (a version different from the online test) on a 5-point scale – as in Experiment 1, but identified their sensitive points after which the sentences started to become incomprehensible. We found the condition (2d) (i.e., 5 consecutive nouns) had the highest percentage of 'stop-making-sense' button-press (29%). Furthermore, regarding the offline GJ data, the results basically replicate Experiment 1 with a much clearer pattern (Fig. 2). When (2c) was set as the baseline, (2c) was rated significantly lower than (2a) (β = 1.04, SE = 0.15, t = 7.12, p < 0.0001) and (2b) (β = 0.73, SE = 0.15, t = 5.00, p < 0.0001), but was rated higher than (2d) (β = -0.75, SE = 0.15, t = -5.13, p < 0.0001) and (2e) (β = -1.04, SE = 0.15, t = -7.12, p < 0.0001). When (2d) was set as the baseline, (2d) was rated significantly lower than (2a), (2b) and (2c) (*p*s < 0.0001). These patterns suggest that participants' acceptability ratings decreased significantly between (2c) (i.e., 4 consecutive nouns) and (2d) (i.e., 5 consecutive nouns).

Taken together, our results showed that the upper limit of processing Chinese possessive chains is four consecutive nouns. Our study supports Cowan's (2001) hypothesis, providing novel evidence for precise quantification of human working memory capacity that underlies language processing.

References
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(1) Sample stimulus set in English gloss (shown in Chinese characters)of Experiment 1

condition	NP1	DE1	NP2	DE2	NP3	DE3	NP4	DE4	NP5	DE5	NP6	DE6	NP7	Predicate
a	My		son	DE	$uncle_m$	DE	daughter	DE	$aunt_m$	DE	elder brother	DE	father	won the prize.
b	My		son		$uncle_m$	DE	daughter	DE	$aunt_m$	DE	elder brother	DE	father	won the prize.
c	My		son		$uncle_m$		daughter	DE	$aunt_m$	DE	elder brother	DE	father	won the prize.
d	My		son		$uncle_m$		daughter		$aunt_m$	DE	elder brother	DE	father	won the prize.
e	My		son		$uncle_m$		daughter		$aunt_m$		elder brother	DE	father	won the prize.

Note: The subscript ‘m’ means ‘on the maternal side’, ‘p’ means ‘on the paternal side’.

(2) Sample stimulus set in English gloss (shown in Chinese characters) inthe online version of Experiment 2, usingself-paced reading with a stop-making-sense task

condition	context	NP1	NP2	NP3	NP4	NP5	NP6	DE7	NP7	Predicate
a	Last night, news program said that	our	son	/	/	/	/	DE	colleague	has brilliant achievements in war
b		our	son	classmate	/	/	/	DE	colleague	has brilliant achievements in war
c		our	son	classmate	uncle	/	/	DE	colleague	has brilliant achievements in war
d		our	son	classmate	uncle	comrade	/	DE	colleague	has brilliant achievements in war
e		our	son	classmate	uncle	comrade	elder brother	DE	colleague	has brilliant achievements in war

Note: The slash ‘/’ means that the slot is not filled in with any lexical content

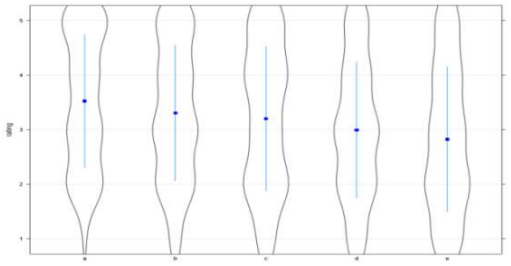

Fig. 1 Mean ratings of GJ in Exp. 1

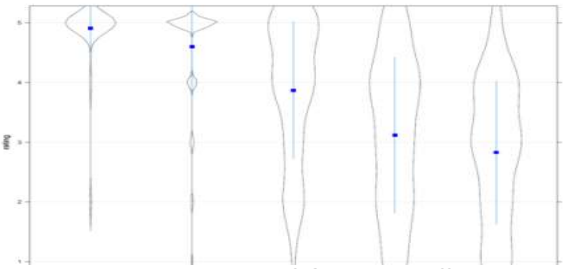

Fig. 2 Mean ratings of GJ in the offline task of Exp. 2