Scope interpretations of Mandarin embedded *wh*-questions: An eye-tracking study

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Non-local dependency in Mandarin *wh*-questions has been extensively researched in theoretical linguistics, but it remains an understudied topic in language processing. Mandarin is a *wh*-in-situ language in which the *wh*-word remains at its thematic position in a *wh*-question. Similar to English, a *wh*-question can be embedded under clausal verbs, but whether it is an interrogative or a declarative clause is determined by the feature of the matrix clausal verb (Huang 1982). For example, the verb 好奇 ('wonder') in (1) has a [+wh] feature, requiring an interrogative complement; thus, (1a) is grammatical while (1b) is not. In contrast, the verb 相信 'believe' in (2) has a [-wh] feature so that *wh*-words are illegal in the embedded sentence.

(1) 赞助商   好奇   电视台   取消了   {a. 哪些/b. *那些}   节目。
     sponsor   wonder   network   cancel-ASP   a. which/b. *those   show
     a. 'The sponsors wonder which shows the network has canceled.'
     b. '*The sponsors wonder that the network has canceled those shows.'

(2) 群众们 相信 市政府   禁止了   {a. *哪些/b. 那些}   行为。
     people believe city-government forbid-ASP a. *which/ b. those   behaviors
     a. '*People believe which behaviors the city government has forbidden.'
     b. 'People believe that the city government has forbidden those behaviors.'

(3) 警察   知道 清洁工   偷走了   {a. 哪些/b. 那些}   文件。
     Police know cleaner   steal-ASP a. which/b. those   documents
     a. 'The police know which documents the cleaner has stolen.
     b. 'The police know that the cleaner has stolen those documents.'

These examples offer a valuable context to study how readers handle non-local dependencies, especially covert ones, compared to *wh*-movement languages. The resemblance between interrogative and declarative readings draws attention to sentence comprehension, particularly when verbs like 知道 ('know') permit both readings. The survey is critical given that native speakers' judgments seem to vary and contextual bias matters (Yang 2012; Xiang et al. 2023).

We conducted two experiments: an acceptability judgment task (n = 42) and an eye-tracking sentence reading task (n = 68), with Mandarin native speakers from China. Our goals were to assess whether linguistic theories' grammatical distinctions align with native speakers' judgments and to explore the processing of covert non-local dependencies in embedded clauses. In *wh*-in-situ sentences with multiple CPs, the scope of wh-phrases varies with verb types and embedded clauses. We examined two key questions: (A) Are native speakers sensitive to clausal verbs' features ([+wh], [-wh], [±wh])? (B) Does feature complexity (unitary vs. dual) affect online processing of embedded wh-questions? Additionally, we investigated whether readers interpret all possible meanings or rely on a simpler, 'good-enough' strategy, before alternative readings are required. The results (Tables 1-2) show that native speakers' judgments were consistent with the feature requirements proposed for the clausal verbs. Verbs with unitary features ([+wh] or [-wh]) were more straightforwardly rated than binary ones ([±wh]). Analyses by clmm() in R show the same results. For the eye-tracking study, we examined how native speakers process different embedded *wh*-scope readings (e.g., (4), see Fig. 1 for an example trial.), based on first fixation duration (FFD), first-pass time (FPT), regression-path duration (RPD), and total reading time (TRT). Four interest areas for analyses are the matrix verb (IA1, e.g., 知道 'know'), the embedded verb (IA2, e.g., 好奇 'wonder'), and the *wh*-phrase (IA3 哪些 'which' and IA4 知识 'knowledge'). The results show that readers appeared to predict embedded clause types based on the matrix and embedded verbs. As shown in Table 3, low-scope sentences (4a) were processed faster than high-scope sentences (4b), supporting processing accounts based on memory retrieval and locality. Moreover, we found no significant differences between low-scope sentences (4a) and ambiguous sentences (4c), suggesting that readers used a good-enough approach rather than parallel parsing (Table 4).

Table 1. Average ratings and standard deviation by each condition

Condition	Mean	SD
1a	4.40	0.91
*1b	1.97	0.90
*2a	2.30	1.16
2b	4.27	1.09
3a	3.84	1.91
3b	3.84	1.24

Table 2. Pairwise comparisons of clmm() results

Contrast	Estimate	SE	z.ratio	p.value
1a-1b	-4.5685	0.479	-9.547	<.0001
2a-2b	3.8149	0.439	8.694	<.0001
3a-3b	-0.0204	0.309	-0.066	.9473
1a-3a	-1.2367	0.400	-3.093	.0020
2b-3b	-1.0046	0.379	-2.661	.0078

(4). 在这学期的期末家长会上,
zai zhe xueqi de qimo jiazhanghui shang,
'At this semester's term-end teacher-parent meeting,'

a. double-embedded low scope
老师 知道 [CP1 家长们 *好奇* [CP2 学生们 学习了 哪些 知识.]]
laoshi zhidao jiazhangmen *haoqi* xueshengmen xuexile **naxie zhishi**
teacher know parents *wonder* students learn-ASP **which knowledge**
'The teacher knew the parents *wondered* **which knowledge** the students had learned.'

b. double-embedded high scope
老师 知道 [CP1 家长们 *觉得* [CP2 学生们 学习了 哪些 知识.]]
laoshi zhidao jiazhangmen *juede* xueshengmen xuexile **naxie zhishi**
teacher know parents *think* students learn-ASP **which knowledge**
'The teacher knew **which knowledge** the parents *thought* the students had learned.'

c. double-embedded ambiguous scope
老师 知道 [CP1 家长们 *清楚* [CP2 学生们 学习了 哪些 知识.]]
laoshi zhidao jiazhangmen *qingchu* xueshengmen xuexile **naxie zhishi**
teacher know parents *understand* students learn-ASP **which knowledge**
'The teacher knew the parents understood **which knowledge** the students had learned.'
(low scope)
'The teacher knew **which knowledge** the parents understood the students had learned.'
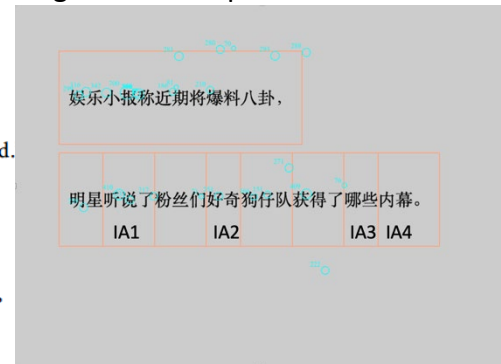(high scope)

Fig. 1. An example trial

Table 3. Results of eye-movement measures of low scope and high scope conditions

4a-4b	IA1	IA2	IA3	IA4
	Estimate, SE, P	Estimate, SE, P	Estimate, SE, P	Estimate, SE, P
FFD	-0.013, 0.02, 0.45	0.036, 0.02, **0.044**	0.065, 0.02, **0.002**	0.033, 0.04, 0.46
FPT	-0.015, 0.02, 0.54	-0.034, 0.02, 0.14	0.065, 0.02, **0.009**	-0.018, 0.05, 0.7
RPD	-0.004, 0.03, 0.88	0.028, 0.04, 0.47	0.036, 0.06, 0.5	0.114, 0.06, 0.07
TRT	0.092, 0.04, **0.029**	-0.036, 0.03, 0.29	0.25, 0.2, 0.21	-0.014, 0.09, 0.88

Table 4. Results of eye-movement measures of low scope and ambiguous conditions

4a-4c	IA1	IA2	IA3	IA4
	Estimate, SE, P	Estimate, SE, P	Estimate, SE, P	Estimate, SE, P
FFD	0.018, 0.02, 0.313	-0.018, 0.02, 0.30	0.024, 0.02, 0.291	0.001, 0.04, 0.91
FPT	0.023, 0.03, 0.35	-0.033, 0.02, 0.17	0.037, 0.02, 0.127	-0.017, 0.05, 0.73
RPD	0.018, 0.03, 0.567	-0.021, 0.04, 0,59	0.056, 0.06, 0.387	-0.002, 0.06, 0.97
TRT	0.041, 0.04, 0.243	0.011, 0.02, 0.81	-0.001, 0.02, 0.99	0.029, 0.06, 0.629

Selected references:
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