

Wh-scope: An experimental study

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1 Introduction

It is commonly assumed that *wh*-questions denote sets of propositions (Hamblin 1973, Karttunen 1977, but see Krifka 2011 for alternative views). However, how these sets of propositions are compositionally derived is still a matter of on-going debate. On one hand, Karttunen (1977) suggested that a *wh*-phrase be analyzed as an existential quantifier quantifying into a set of propositions. The quantification is facilitated by a scope-taking mechanism that allows the *wh*-phrase to assume a scopal position at the clausal periphery. This approach has been widely adopted and developed, by Huang (1982b), Dayal (1996), Ciardelli et al. (2017) and Charlow (to appear). On the other hand, Hamblin (1973) proposed an alternative way for deriving sets of propositions, using a special composition mode that allows set expansion. To simply put, a *wh*-phrase is taken to denote a set of alternatives, and the set is allowed to expand with help of set-friendly function application, often known as point-wise function application. The end product of this set expansion is a set of alternative propositions, that is, the same product derived from Karttunen's scope taking approach. This approach has been recently revived by Kratzer & Shimoyama (2002) and Shimoyama (2006) and have been adopted by Dong (2009, to appear), He (2011) and Kotek (2014).

Since both approaches lead to very similar end products and no extant empirical arguments truly favor one over the other (see section 2.1), many think that it's impossible to tease apart these two approaches. However, some scholars, for example, Dong (2009), are aware that the two approaches make different predictions regarding a phenomenon known as selective wide scope. Selective wide scope taking has been extensively researched in the literature of indefinites (Reinhart 1997; Winter 1997; Charlow to appear), but has only received very limited discussion in the literature of questions (see, for example, Baker 1970; Karttunen 1977). In addition, the grammatical status of selective wide scope taking in *wh*-questions has remained highly controversial, which undermines its role in addressing the debate on question composition. The primary contribution of the present study lies in addressing the murky grammatical status of selective scope taking in *wh*-questions.

More concretely, I conducted two experiments addressing whether two in-situ *wh*-phrases can selectively take wide scope over a question-selecting verb. For example, the *wh*-phrases in the following Mandarin sentence potentially have three scope arrangements, yielding three interpretations—the subject selective wide scope reading, shown in (1-a), the object selective wide scope reading, shown in (1-b), and the narrow scope reading, shown in (1-c).

- (1) Libai zhidao Dufu xiang wen shei mai-le shenme.
Libai know Dufu want ask who buy-ASP what
a. 'Libai knows who is the person such that Dufu is asking what she bought.'

- b. ‘Libai knows what is the thing such that Dufu is asking who bought it.’
- c. ‘Libai knows Dufu is asking who bought what.’

In the first two readings, one of the two *wh*-phrases (i.e., the subject in (1-a) and the object in (1-b)) scopes over *wen* ‘ask’ but the other scopes under this verb. They are selective wide scope readings. In (1-c), both *wh*-phrases are scoped over by *wen* ‘ask.’ In other words, it is a narrow scope reading.

In Section 2.1, I elaborate on how the scope-taking approach and the set-expansion approach make different predictions about the selective wide scope reading. In particular, the scope-taking approach predicts that selective wide scope is available in *wh*-questions, and hence (1-a) and (1-b) are indeed possible readings of (1), in addition to (1-c). However, the set-expansion approach fails to generate selective wide scope readings, making (1-c) the only reading available to (1). Whether (1-a) and (1-b) are acceptable is still disputed in the literature. Huang (1982b) has argued in favor of the grammatical status of selective wide scope readings in Mandarin *wh*-questions, but many studies, such as Xu (1990) and Lin (1992), have expressed doubts towards Huang’s conclusion.

Two experiments were conducted to probe the readings available to sentences like (1). The first study used a binary truth value judgment task and the second study featured a felicity judgment task based on a 5-point Likert scale. Both studies showed that the selective wide scope reading, though not being the preferred reading, is nonetheless available to at least a subgroup of the population.

The rest of the paper is organized as follows. Section 2 lays out the theoretical background of *wh*-question composition, focusing on the scope-taking approach and the set-expansion approach and their respective predictions. Section 3 presents the first experiment, which probes the grammatical status of selective wide scope using a binary truth value judgment task. Section 4 reports the second experiment, which differed from the first experiment in that the responses were coded on a continuous, Likert scale of felicity rather than on a binary scale. Section 5 synthesizes the findings in the two experiments to address the research question at hand, and offers some remarks for future study. Section 6 concludes the paper.

2 Background

2.1 Two approaches to composing *wh*-questions

A prominent approach to the semantics of *wh*-questions models them as sets of alternative propositions. Two representative approaches in this tradition are Hamblin (1973) and Karttunen (1977). Their common core lies in treating *wh*-questions as sets of propositions. For example, assuming a small domain consisting of three individuals Mary, Peter and Jane, the question *who met Lee* denotes a set of propositions as shown in (2). Each proposition in the set is a potential answer to the question.

- (2) $[[\text{Who met Lee}]] = \{\text{Mary met Lee, Peter met Lee, Jane met Lee}\}$

Because of this united view on the meaning of *wh*-questions, Hamblin (1973) and Karttunen (1977) are usually treated on a par when different approaches to questions are compared (e.g., Heim 2011, Krifka 2011, Dayal 2017).

However, these two approaches arrive at the end product, i.e., sets of propositions, via different routes. The difference lies in the compositional mechanism giving rise to the sets of propositions.

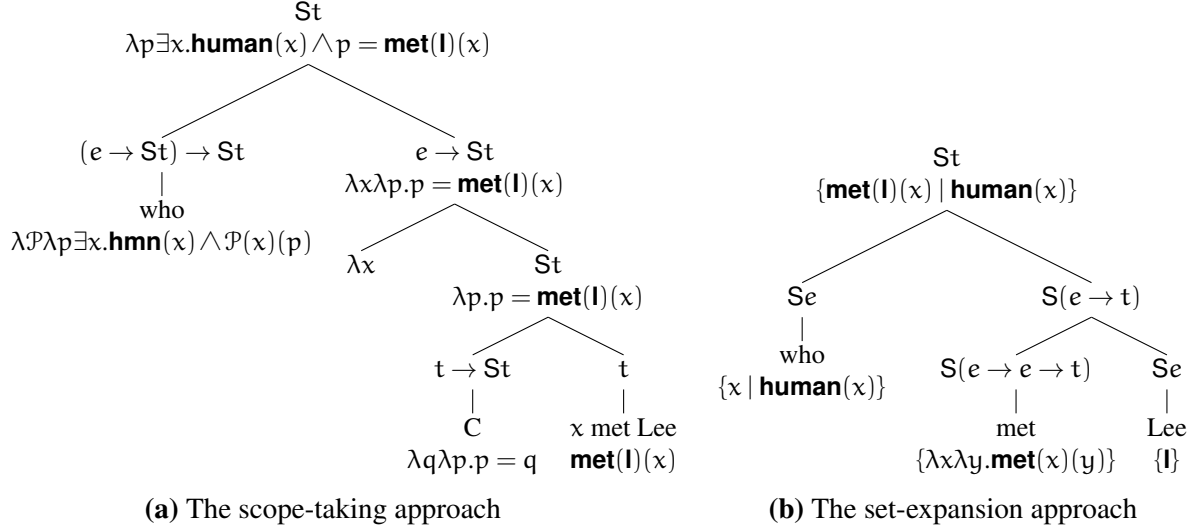


Figure 1: The scope-taking approach vs. the set-expansion approach

In particular, Karttunen’s study represents a **scope-taking approach**. It takes a *wh*-phrase as a generalized quantifier scoping over a set of propositions, as exemplified in (3). A note on notational conventions: throughout the paper, $S\alpha$ is the abbreviation of the type $\alpha \rightarrow t$, i.e., a set of type- α entities¹. In other words, the scope argument of a *wh*-phrase is a function from individuals to sets of propositions.

$$(3) \quad \llbracket \text{who} \rrbracket = \lambda P \lambda p \exists x. \text{human}(x) \wedge P(p)(x) \quad \text{who} :: (e \rightarrow St) \rightarrow St$$

A sample derivation of the question in (2), i.e., *who met Lee*, is given in Figure 1a. Following Heim & Kratzer (1998), I present the scope-taking mechanism using Quantifier Raising (QR). The root denotation of a *wh*-question is derived via ordinary Function Application (FA) rule and with help of the Proto-Question rule in Karttunen (1977) that is ascribed to a set-generating operator, i.e, the complementizer C in many GB-style LFs. The scope-taking approach has been adopted by Huang (1982a), Dayal (1996), Ciardelli et al. (2017), Charlow (to appear) and many other studies.

On the contrary, Hamblin’s study represents a **set-expansion approach**, which does not rely on taking *wh*-phrases to be quantifiers that take scope. Instead, a *wh*-phrase denotes a set of alternatives in this approach, as shown in (4).

$$(4) \quad \llbracket \text{who} \rrbracket = \{x \mid \text{human}(x)\} \quad \text{who} :: Se$$

In this approach, all the lexical items have set denotations. Non-*wh*-items simply denote singleton sets of their ordinary denotations. For example, *Lee* denotes a singleton set of the proper name **l**. The set denoting items are composed via a set-friendly compositional rule—Pointwise Function Application (PWFA), as defined in (5).

$$(5) \quad \frac{\llbracket A \rrbracket = F : S(\sigma \rightarrow \tau) \quad \llbracket B \rrbracket = X : S\sigma}{\llbracket A B \rrbracket = \{f(x) \mid f \in F \wedge x \in X\} : S\tau} \text{PWFA}$$

¹In the studies of questions, propositions are assumed to be intensional, i.e., they denote sets of possible worlds. Since intensionality is not related to the issue addressed in the paper, I ignore the intensional details for simplicity.

As demonstrated by the sample derivation in Figure 1b, the set of alternatives denoted by *who* expands upward, giving rise to a set of propositions. Once the intended scope is reached, alternatives may be ‘bound’ or closed off by an associated operator, essentially stopping the set expansion. This approach was revived after a series of studies by Kratzer and Shimoyama (Kratzer & Shimoyama 2002, Shimoyama 2006) and have been adopted by Dong (2009, to appear), He (2011), Kotek (2014), Tsai (2015) and many other studies.

The scope-taking approach differs from the set-expansion approach regarding the way for marking the scope of *wh*-phrases. Consider the embedded *wh*-question in (6), in which the scope of *who* is restricted to the complement of the question selecting verb *wonder*.

- (6) Kim wonders who met Lee.
- a. Kim wonders [who λx . [x met Lee]]
 - b. Kim wonders [who met Lee]

In the scope-taking approach, *wh*-phrases themselves take scope. In (6-a), the scope of *who* is marked by the landing site of QR. By contrast, the set-expansion approach hypothesizes that *who* is not a scope-bearing element and its scope is marked by an operator that operates on the set of propositions, like *wonder*.

It is not easy to tease apart these two scope marking strategies in *wh*-movement languages, since the scope of *wh*-phrases has been marked in syntax via movement. However, they make different predictions for *wh*-in-situ languages. The first difference concerns island sensitivity. It is generally assumed that scope achieved via QR is sensitive to islands (May 1977), but scope achieved via sets of alternatives is not. Since island insensitivity has been observed for in-situ *wh*-phrases (Huang 1982a; Pesetsky 1987; Nishigauchi 1990; Reinhart 1998; a.o.), the set-expansion approach has been argued to have an advantage over the scope-taking approach (Shimoyama 2006; Dong 2009; He 2011). However, Charlow (to appear) has enriched the scope-taking approach with a mechanism that allows alternative sets to take scope. His analysis successfully predicts the island insensitivity of in-situ *wh*-phrases, neutralizing the different predictions of the two approaches regarding island sensitivity. I will return to Charlow’s approach in Section 5.

The second difference concerns selective wide scope in multiple *wh*-questions. The scope-taking approach predicts that in a multiple *wh*-question the *wh*-phrases can take scope in different positions. For example, (7) is ambiguous between two readings (Baker 1970; Karttunen 1977; Dayal 1996). In the first reading, *where* and *which book* both take scope within the complement of *remember*, as shown in (7-a). The answer to this question would be ‘John’ or ‘Sue.’ In the second reading, the scope of *where* is under *remember*, but *which book* can take scope over it, as shown in (7-b). Then, the answer would be a pair-list one: ‘John remembers where Mary keeps *War and Peace*, Peter remembers where Mary keeps *Price and Prejudice*.’

- (7) Who remembers where Mary keeps which book?
- a. both *wh*-phrases take narrow scope
who remembers [which place λz [which book λy [Mary keeps y in z]]]
 - b. *who* takes selective wide scope
who λx [which book λy [x remembers [where Mary keeps y]]]

By contrast, in the set-expansion approach, scope via alternatives does not tolerate an inter-

vening operator that associates with sets of alternatives. As shown in Figure 2, which illustrates the derivation of (7), the alternative sets introduced by *where* and *which book* ‘mix’ via PWFA, generating a set of propositions. *Remember* takes the set of propositions as argument and returns a singleton set of an $(e \rightarrow t)$ -type function.² Here, **ans** is an answerhood operator, which maps a question onto its (exhaustive) true answer in the evaluation world (see Dayal 1996).

$$(8) \quad \llbracket \text{remember} \rrbracket = \lambda Q. \{ \lambda x. \text{remember}(\text{ans}(Q))(x) \} \quad St \rightarrow S(e \rightarrow t)$$

When *remember* combines with the question via function application, the alternative sets denoted by the two *wh*-phrases are not available for the further composition. As a result, neither *where* nor *which book* is able to take scope beyond *remember*. Hence, the availability of (7-b) challenges the Hamblin composition.

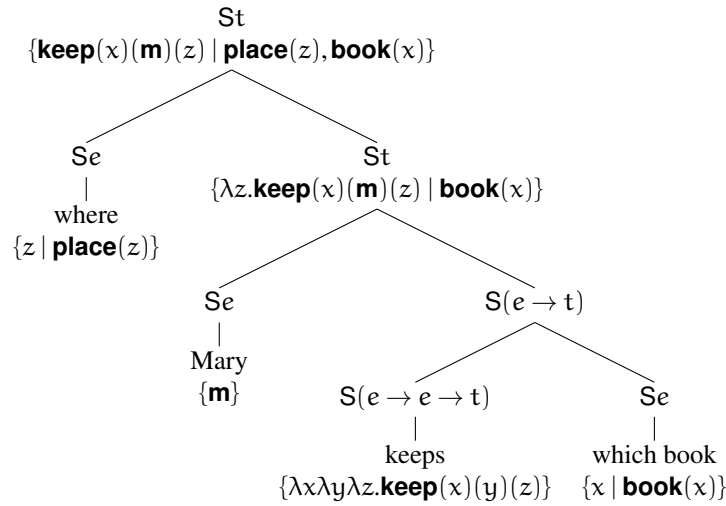


Figure 2: Derivation of a multiple *wh*-question in the set-expansion approach

Nevertheless, the scope-taking approach also predicts an impossible reading for (7), i.e., the one with *where* scoping over *remember*, and *which book* under it. Karttunen (1977) suggests that the unavailability of this reading is due to syntactic reasons. In particular, English as a *wh*-movement language requires *wh*-phrases to move to the specifier of CP overtly to mark scope. As a result, *where* in (7) moves in syntax and its scope is marked. To take scope over *remember*, it is required to move from a position on which its scope is already mark syntactically.

Karttunen (1977) himself is aware of a potential test for his suggestion. In particular, he notes that if his suggestion is on the right track, we can expect more ambiguities in *wh*-in-situ languages, in which *wh*-movement is not required to form a question. For this reason, *wh*-in-situ languages provide an important avenue for testing the scope potentials of interrogative *wh*-phrases.

In fact, Huang (1982a,b) makes a crucial observation in support of the scope-taking approach to question composition. He has observed that in-situ *wh*-phrases in Mandarin can selectively take

²It should be pointed out that question selecting verbs cannot be composed with questions via PWFA. These verbs take the whole set of propositions as argument, instead of a proposition in the set. Consequently, we need to use ordinary function application to compose them with questions. This operation does not follow the basic mechanism assumed in the set-expansion approach. Strictly speaking, it is a problem for the set-expansion approach, but I'm not taking issues with it here.

scope. Consider the following sentence:

- (9) Libai xiangzhidao shei mai-le shenme liwu?
 Libai wonder who buy-Asp what gift
 a. ‘Who was the person x such that Libai wonders what gift x bought?’
 b. ‘What was the gift y such that Libai wonders who bought y ?’

In this example, the main verb *xiangzhidao* ‘wonder’ is a question-selecting predicate. Therefore, it requires its complement to be a question, but the whole sentence can also be interpreted as a question. Either *shei* ‘who’ or *shenme liwu* ‘what gift’ is able to scope over the question-selecting verb *xiangzhidao*. Since Mandarin is a typical *wh*-in-situ language, no overt syntactic operation interferes with the scope taking of *wh*-phrases. It follows the scope-taking approach that either *wh*-phrase can take scope over the verb.

On the contrary, the set-expansion approach predicts that (9) cannot receive an interrogative interpretation for the same reason that (7-b) is blocked in the approach. If (9) is acceptable, it indeed calls the set-expansion approach into question. However, this data point is highly controversial. Tang (1988), Xu (1990) and Lin (1992) disagree with Huang’s judgement. They argue that (9) only has one reading with the scope of both *wh*-phrases restricted to the embedded clause, as predicted by the set-expansion approach. Moreover, Xu remarks the two selective wide scope readings of (9) are allowed only when the *wh*-question was used as an echo question.

To address the controversy over the selective wide scope potential of *wh*-phrases in Mandarin, I conducted two experiments to test Huang’s observation. According to the results, the two readings of (9) are natural, though they are not preferred. Hence, the scope-taking approach has an advantage over the set-expansion approach, since the former at least allows the selective wide scope reading for in-situ *wh*-phrases. In Section 5, I discuss the possibility that the dispreference is due to processing load.

2.2 Experimental work on the scope of in-situ *wh*-phrases

Xiang has led a series of experimental studies on the scope of Mandarin in-situ *wh*-phrases (Xiang et al. 2013, 2015, 2017). For example, Xiang et al. (2015) examined the online processing of Mandarin *wh*-in-situ constructions with use of a self-paced reading task and eyetracking. The experiment results show that *wh*-in-situ constructions with intervening embedded clausal structures, as shown in (10-a), evoke an additional processing cost compared to other *wh*-constructions that do not contain intermediate embedded clauses, as shown in (10-b), in online reading times.

- (10) a. ... wonder [_{CP} ... announce [_{CP} ... WH]]
 b. ... wonder [_{CP} ... WH]

They interpret these findings as the result of memory retrieval interference. In (10-a), both the intermediate CP and the higher CP in (10-a) are potential scope positions for the in-situ *wh*-phrase. If comprehending *wh*-in-situ questions needs constructing a covert dependency between in-situ *wh*-phrases and scope positions, a backwards retrieval process will be initiated to find the correct scope position that the *wh*-phrase is associated with. Under the scenario that the retrieval target is the higher CP, the intermediate CP should induce the interference effect of comprehension. By contrast, the interference is not observed in (10-b), which does not have the intermediate CP.

Therefore, establishing the covert dependency in (10-a) results in increased processing costs.

Accordingly, it is experimentally attested that in-situ *wh*-phrases have non-local scope interpretation. Nevertheless, these experiment findings do not address the question of selective wide scope taking. The test sentences of these experiments only involve one *wh*-phrase. Both the scope-taking approach and the set-expansion approach predict that the scope of an in-situ *wh*-phrase is located in the clause edge position.

Dong (to appear) conducted experiments to examine the interaction of prosody and the scope of Mandarin in-situ *wh*-phrases. It is shown that an embedded in-situ *wh*-phrase takes wide scope if it is the most phonologically prominent item in the matrix clause. Additionally, he tested the selective wide scope reading. In particular, his study involved two experiments—a production experiment and a perception experiment. In the production experiment, the conductor read part of a written conversation like (11)A, and the participant read the rest of the conversation, like (11)B. The last sentence of the conversation was recorded. Four native speakers attended the production experiment. Only one speaker assigned the highest pitch to the embedded subject *wh*-phrase.

- (11) A: Huang Rong saw that some students took some things from the office. So obviously she knows what these students took.
B: But there are so many students. I don't think all of them took some things from the office. So...
- Huang Rong mingbai shei mai-le shenme?
Huang Rong know who buy-Asp what
'Who was the person such that Huang Rong knows she bought what?'

In the perception experiment, the recorded sentences were played without any context to four different native speakers and they were asked to indicate whether they heard a declarative sentence or a question. According to the results, the correctness ratio was only 56.25%, which is close to a 50-50 guess. The listeners did not have clear cues to whether the sentence is a question.

In short, *wh*-phrases that selectively take wide scope did not have phonological prominence. Considered in conjunction with the finding that simple *wh*-questions do exhibit phonological prominence on the *wh*-phrases that take sentential scope, Dong (to appear) concluded that the selective wide scope reading does not have a designated intonation pattern in real conversations. He further suggested that this reading might not be natural.

However, these findings are inconclusive with respect to the existence of the selective wide scope reading. As noted by Dong himself, the absence of a special intonation for the selective wide scope reading may be due to the complexity of the reading task involved. It does not exclude the possibility that the selective wide scope reading is grammatically allowed. Moreover, the experiments did not directly test whether the selective wide scope reading is available, but rather whether the native speakers assign the highest pitch to in-situ *wh*-phrases that take selective wide scope.

2.3 Interim summary

In short, the selective wide scope potential of *wh*-phrases in multiple *wh*-in-situ questions holds the key to choosing between the scope-taking approach and the set-expansion approach to composing *wh*-questions. However, none of the extant experimental studies on scope-taking of *wh*-phrases in

questions actually looked at the scope potential of *wh*-phrases in multiple *wh*-questions embedded by another question-taking predicate, so their conclusions do not shed light on the selective wide scope potential of *wh*-phrases. Moreover, the few theoretical studies that actually concerned these selective wide scope configurations failed to lead to a conclusive generalization about the selective wide scope potential of in-situ *wh*-phrases.

To fill the research gap on the selective wide scope potential of in-situ *wh*-phrases, two experiments have been conducted. Experiment 1, discussed in section 3, examines the range of scope potentials for a multiple in-situ *wh*-question embedded by a question-taking predicate by using a binary acceptability judgment task. Experiment 2, discussed in section 4, has a setup very similar to Experiment 1, but the task involved is an acceptability judgment task involving a continuous, Likert scale.

There are a few reasons for having two different tasks targeting essentially the same scope behavior. First, having two very similar experiments ensure the replicability of the results. As it will be shown in the discussion of the two experiments, testing scope taking with multiple *wh*-questions is an formidable mission. Many participants failed to pass the control items, even more failed to complete the experiments. It is thus worthwhile to set up more than one experiment to ensure the replicability of the results. Second, setting up the second experiment with a Likert scale rather than a binary scale allows us to capture more gradience in participant response, something not easily obtainable from the binary nature of the scale used in the first experiment.

3 Experiment 1

3.1 Materials

The experiment involved presenting subjects with a concrete scenario consisting of a short descriptive passage and some human characters expressing the information they knew or would like to know. The participants were asked to evaluate, based on the scenario, the **correctness** of a sentence involving two *wh*-phrases. In this experiment, correctness is set on a binary scale, so participants may either choose **correct** or **incorrect**, depending on the scenario and the sentence presented. The following subsections present the materials used in the experiment.

3.1.1 Embedded questions

Three key structural elements are needed for testing selective scope taking: (i) a question-selecting verb, (ii) a *wh*-phrase to be interpreted inside the scope of the question-selecting verb, and (iii) a *wh*-phrase to be interpreted outside the scope of this verb. Potential direct questions like (9), used by Huang (1982b), have all these three elements and hence could be used as test items. However, it has been challenged that direct questions cannot be reliably used to test selective wide scope due to the availability of the echo question reading (Xu 1990). The argument is that to the extent that (9) can be used as a direct question for asking the identity of the buyer, it may not be due to the subject *wh*-phrase taking selective wide scope, but due to the question being used as an echo question.

To address this concern, in this study a question-selecting verb is further embedded to give rise to a matrix indirect question of the form in (12). Like Huang's sentences, this sentence is also ambiguous between three readings depending on the scope of the subject *wh*-phrase and the

object *wh*-phrase. If the subject *wh*-phrase alone takes scope out of the lower predicate *wen* ‘ask’, the resulting interpretation is (12-a). If it is the object *wh*-phrase that takes scope out of the lower predicate, the corresponding interpretation is (12-b). Lastly, if none of the *wh*-phrases scopes above the lower predicate, the interpretation hence derived is (12-c).

- (12) Libai zhidao Dufu xiang wen shei mai-le shenme liwu.
 Libai know Dufu want ask who buy-Asp what gift
 a. ‘Libai knows who is the person *x* such that Dufu is asking what gift *x* bought.’
 b. ‘Libai knows what is the gift *y* such that Dufu is asking who bought *y*?’
 c. ‘Libai knows Dufu is asking who bought what gift.’

The lower question-selecting verb is always *wen* ‘ask’, which *obligatorily* selects a question as its complement. An obligatory question-selecting verb was used for this position so that at least one of the *wh*-phrases had to take narrow scope to generate the question meaning required by the lower verb. The higher question-selecting verb is *zhidao* ‘know’, which *optionally* selects a question as its complement. This optional question-selecting verb allowed any of the three readings to surface, and hence a participant was free to choose the desired reading based on whether their preference for selective wide scope.

In addition, since no quantitative baseline has been established for judging the selective wide scope behavior of *wh*-phrases, a set of items were included for setting up such a baseline. The baseline items differ from the target items minimally in terms of the matrix verb—while the target items have a optional question-taking predicate *zhidao* ‘know’ to allow for flexible scope behavior, the baseline items have a non-question-selecting verb *renwei* ‘think’, which allows neither of the *wh*-phrases to take selective wide scope over the lower embedding predicate, as illustrated in (13).

- (13) Libai renwei Dufu xiang wen shei mai-le shenme liwu.
 Libai think Dufu want ask who buy-Asp what gift
 a. #‘Libai thinks who is the person *x* such that Dufu is asking what gift *x* bought.’
 b. #‘Libai thinks what is the gift *y* such that Dufu is asking who bought *y*.’
 c. ‘Libai thinks Dufu is asking who bought what gift.’

Since *wh*-phrases may not take selective wide scope in the THINK type sentences, both the scope taking approach and the set expansion approach expect them to be incorrect against the scenarios that support the selective wide scope interpretation. If there were participants judging in-situ *wh*-phrases to selectively take wide scope in these scenarios, their contribution would be regarded as the noise baseline. The baseline items are only compatible with a narrow scope interpretation of the two *wh*-phrases. For the *wh*-phrases in the target sentences with *zhidao* ‘know’ to be justified for selective wide scope, they have to fare significantly better than the *wh*-phrases in the baseline items involving *renwei* ‘think’.

In short, two matrix predicates are used to construct indirect questions for testing the selective wide scope behavior of *wh*-phrases. The schema for the indirect questions is given in (14).

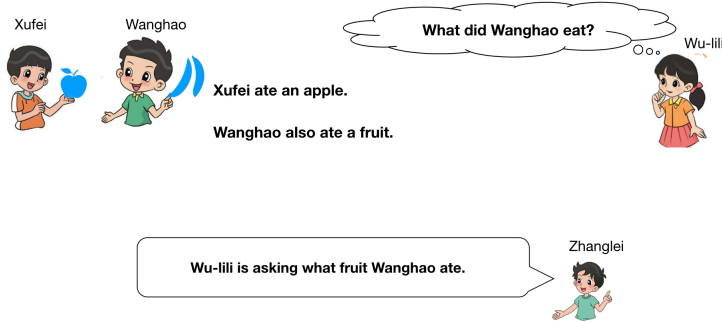
- (14) Subject₁ $\left\{ \begin{array}{c} V_1 \\ \textit{zhidao} \text{ ‘know’} \\ \textit{renwei} \text{ ‘think’} \end{array} \right\}$

$$\text{Subject}_2 \quad \begin{matrix} V_2 \\ \{ \text{wen 'ask'} \} \end{matrix} \quad \left[\text{shei 'who'} \quad V_3 \quad \text{shenme-NP 'what-NP'} \right]$$

Here V_1 is the matrix predicate, which alternates between an optional question-taking predicate *zhidao* ‘know’ for the target items, and a non-question-taking predicate *yiwei* ‘think’ for the baseline items. V_2 is the lower embedding predicate, which is always an obligatory question-taking predicate. As for the two *wh*-phrases, they are controlled to be *shei* ‘who’ for the *wh*-phrase in the subject position, and *shenme* ‘what’ plus a scenario-appropriate NP for the *wh*-phrase in the object position. All other phrases are allowed to differ based on the scenario.

3.1.2 Binary truth value judgment task

Switching to indirect, embedded questions like (12) also made it possible to probe the scope behavior of *wh*-phrases with a simple truth value judgment task. Using a binary truth value judgment task with the options *dui* ‘correct’ and *budui* ‘incorrect’, a participant was instructed to judge the correctness of an indirect question against a background scenario, as shown in the sample task in Figure 3.



According to the scenario consisting of pictures and texts, is the following sentence correct or not?

Zhanglei zhidao Wu-lili xiang wen shei chi-le shenme shuiguo.
 Zhanglei know Wu-lili want ask who eat-Asp what fruit

Correct

Incorrect

Figure 3: A sample target item

Crucially, if a participant judged a sentence to be correct in a scenario supporting selective wide scope taking of a *wh*-phrase, we inferred that the participant allowed the *wh*-phrase to selectively take scope out of the lower predicate, providing support for the scope taking approach. Otherwise,

we concluded that the participant was only able to assign the *wh*-phrase the narrow scope reading, providing support for the set expansion approach.

For concreteness, in this sample task, which depicts a scenario supporting selective wide scope of the subject *wh*-phrase, a participant was asked to compare Wu-lili's question with Zhanglei's knowledge of Wu-lili's question. If a participant judged the sentence to be 'correct', then we could infer that they were interpreting the sentence in the following way:

- (15) 'Zhanglei knows who is the person x such that Wu-lili is asking what fruit x ate.'

In the target sentence, the multiple *wh*-question is embedded by two question-selecting verbs. The lower one (V_2) is a verb that obligatorily selects a *wh*-question; while the higher one (V_1) is a verb that optionally selects a *wh*-question. According to the background story, Wu-lili wondered what fruit Wanghao, instead of Xufei, ate and Zhanglei knew this fact. In other words, Wu-lili did not enquire the person who ate fruit so the in-situ *wh*-phrase *shei* 'who' should take scope over the verb *wen* 'ask'. This is only possible if a scope taking mechanism is used to generate the interpretation of the question.

On the other hand, if a participant judged the sentence to be 'incorrect', then we could infer that they did not allow *shei* to selectively take wide scope, i.e., the target sentence has the following interpretation:

- (16) 'Zhanglei knows Wu-lili is asking who ate what fruit.'

The embedded multiple *wh*-question can receive a pair-list reading or a single-pair reading. However, neither reading is verified by the background story. First, Wu-lili did not request the answer to *shei* 'who.' Second, she did not ask what fruit Xufei bought, and hence the pair-list reading is impossible. Therefore, if the target sentence only has the LF (16), as predicted by the set expansion approach, it should be judged incorrect.

3.1.3 Scope patterns

The background scenarios accompanying the target stimuli are categorized into three types depending on the position of the *wh*-phrase that selectively takes scope. The first type, referred to as SUBJ-WIDE here, set up a scenario in which the target sentence is true if the subject *wh*-phrase selectively takes wide scope. The second type, referred to as OBJ-WIDE here, demonstrates a scenario in which a target sentence is true if the object *wh*-phrase selectively takes wide scope. The third type, referred to as NS (narrow scope), describes a scenario in which a target sentence is true if both *wh*-phrases are scoped over by the lower embedding verb. In other words, in these scenarios neither the subject *wh*-phrase nor the object *wh*-phrase selectively takes wide scope. Since both the scope-taking approach and the set-expansion approach are compatible with all *wh*-phrases taking narrow scope, test sentences are expected to be judged 'correct' in the NS scenarios. Although these items are not the primary concern of this study, there were included as controls to ensure that participants understand the task properly and are behaving as expected.

A sample of the three types of scenarios is given in Figure 4. Specifically, in SUBJ-WIDE, Wu-lili only wanted to know the information on the fruit; in OBJ-WIDE, she is only asking who was the person that ate a pear; in NS, she inquires about both the person and the fruit³.

³The NS scenario supports a single pair answer to the multiple *wh*-question embedded in a test sentence. Anna

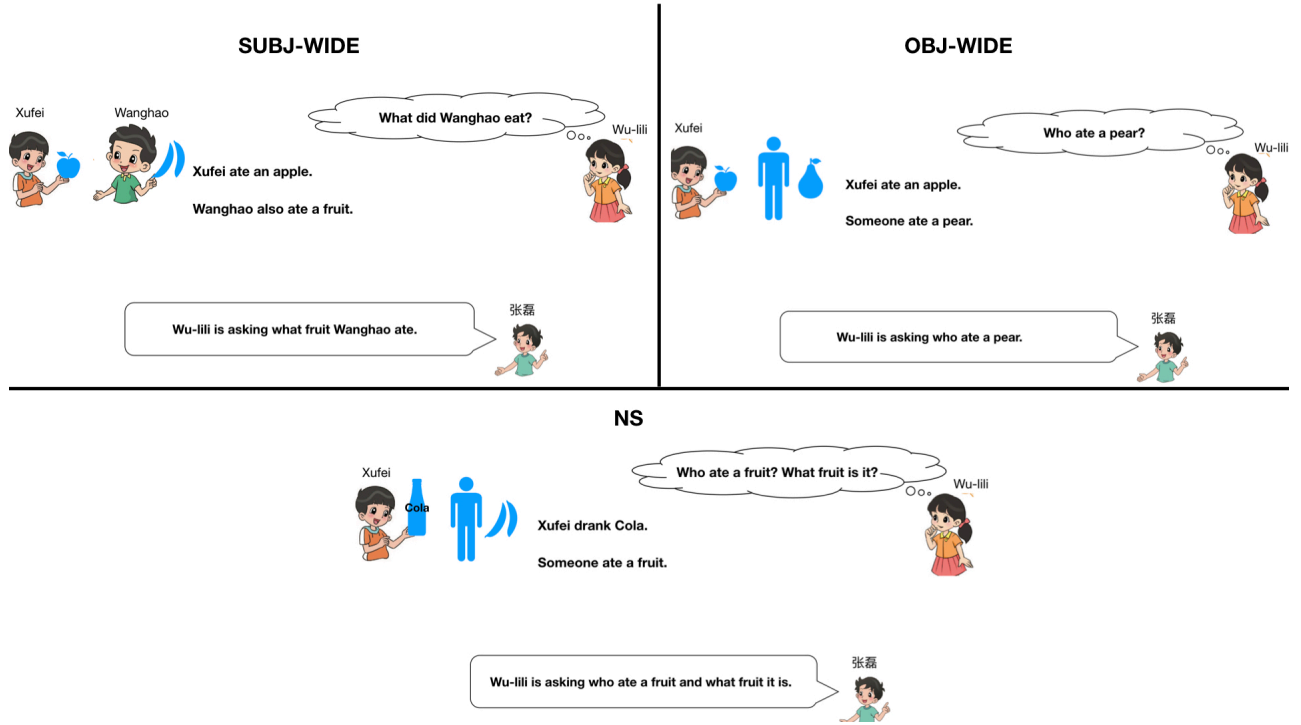


Figure 4: A sample of SUBJ-WIDE, OBJ-WIDE and NS

Crossing the two types of predicates and the three types of scope patterns (supported by the scenarios) results in six conditions. The predictions regarding these conditions from the scope-taking approach and the set-expansion approach are summarized in Table 1. The white blocks represent control items, lightgray blocks baseline items, and darkgray blocks target items.

	SUBJ-WIDE		OBJ-WIDE		NS	
Hypothesis	KNOW	THINK	KNOW	THINK	KNOW	THINK
Karttunen	Correct	Incorrect	Correct	Incorrect	Correct	Correct
Hamblin	Incorrect	Incorrect	Incorrect	Incorrect	Correct	Correct

Table 1: Judgments predicted by the scope taking and set expansion approaches

3.1.4 Additional controls

In addition to items with *renwei* ‘think’ as the baseline and NS scenarios as a control, two other control items were included. The SCOPE control was used to ensure that the participants allow in-situ *wh*-phrases to take scope beyond a clausal boundary. This control item is given in (17), in which the second verb *shuo* ‘say’ is a non-question-selecting verb.

Szabolcsi (p.c.) points out that in some languages like Hungarian multiple *wh*-questions has only the pair-list reading. Mandarin differs from these languages in that the single pair answer and the pair list answer are equally acceptable for a multiple *wh*-question (Liao & Wang 2007; Li & Law 2016).

- (17) Zhanglei zhidao Li xiansheng shuo shei zuo-le yi-dao wuli ti.
 Zhanglei know Li Mr. say who do-Asp one-Cl physics exercise
 ‘Zhanglei knows who is the person such that Mr. Li said she did a physics exercise.’

In this case, the in-situ *wh*-phrase has to scope over *shuo* ‘say’. The background scenario of (17) describes a situation in which the sentence is true. Hence, if it is possible for a participant to scope the *wh*-phrase out of the embedded clause, they should judge (17) to be ‘correct’.

The PRES control was included to make sure that participants map presupposition failure to ‘incorrect.’ The target items has the verb *zhidao* ‘know’ as the matrix embedding predicate, which has a factivity presupposition. When only the NS interpretation is available to a participant in a selective wide scope scenario, the content embedded under *zhidao* ‘know’ essentially fails the factivity presupposition for the participant. In order to make sure that the participant maps presupposition failure to ‘incorrect’ rather than ‘correct’, a control item is included to verify this mapping.

Take as an example the target item shown in Figure 3. Suppose that a participant does not allow either *wh*-phrase to selectively take wide scope, she will interpret the test sentence as ‘Zhanglei knows Wu-lili is asking who ate what fruit.’ Because of the factivity presupposition of *zhidao* ‘know’, the information that Wu-lili does not know who was the person that ate fruit must be taken as granted. However, the background scenario does not support this. It shows that Wu-lili knows Xufei and Wanghao ate fruit. Theoretically, a sentence is not false but lacks a truth value if its presupposition is not true. In fact, Schwarz’s (2016) experiments have shown that people tend to judge a sentence false but need more time to react when its presupposed content is falsified by the context. Therefore, it is expected that the participant chooses ‘incorrect’ if she only has the narrow scope reading for both *wh*-phrases. In order to further verify that participants know how to make truth value judgment in case of presupposition failure, they are asked to judge the following sentence, i.e., the PRES control, against a scenario in which Sunxin only likes singing.

- (18) Zhanglei zhidao Sunxin xihuan da lanqiu.
 Zhanglei know Sunxin like play basketball
 ‘Zhanglei knows Sunxin likes playing basketball.’

3.2 Design, procedure and participants

The six conditions are further crossed with six carrying scenarios to create token variations, generating a total of 36 items. These items were evenly divided into six lists using a Latin-Square design. The two additional control items SCOPE and PRES were added to each list, giving rise to a total of eight experiment items in each list. There were also six filler items, in addition to the eight experiment items, in each list. All the items in each list were pseudo-randomized, and were presented in Simplified Chinese characters, on the online survey platform Qualtrics.

A total of 168 subjects participated in this study. They were mostly college students studying in various universities in Mainland China, recruited with the generous help of their course instructors. A small number of the participants might be personal friends of these instructors and hence might not be college students. Since the survey was anonymous, these participants could not be told apart. All of the participants volunteered to participate in experiment and received no compensation.

3.3 Results

3.3.1 Data preparation

Although a total of 168 online surveys were collected, around a quarter of them were incomplete and hence removed from data analysis. The remaining 125 completed surveys were subject to further screening by the control items. Among them, 31 failed one of the controls items PRES or SCOPE. Their data were excluded. The last type of control items is the NS control. Recall that the NS control items do not distinguish between the scope-taking approach and the set-expansion approach, as they both predict the availability of the narrow scope interpretation, and thus the *dui* ‘correct’ response in the NS control. There were two NS control items for each participant. Only data points from those participants who passed both NS control items were kept. The NS control removed an additional 21 participants, leaving 73 participants for data analysis. Since each participant contributed four data points, two for the target condition and two for the baseline condition, there were a total of 292 data points for analysis.

3.3.2 Data analysis

The overall results of Experiment 1 are presented in Figure 5. The numbers of the ‘correct’ responses are given above the bars. Three points are worth highlighting in this figure. They are discussed below.

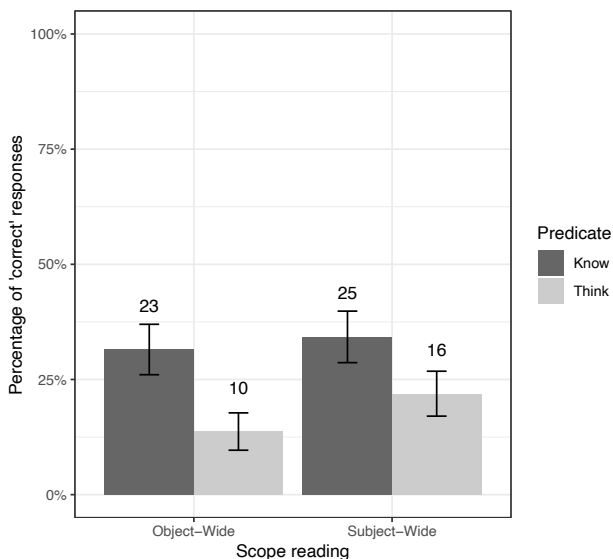


Figure 5: Results of Experiment 1

To begin with, a selective wide scope interpretation of both *wh*-phrases is available. This can be seen by comparing the percentage of ‘correct’ responses for the KNOW condition and the THINK condition in Figure 5. Recall that the THINK condition is intended to serve as the baseline, as it does not support any selective wide scope interpretation, while the KNOW condition is intended to probe the selective scope possibility. There is a small number of people that did not behave as expected in the THINK condition, allowing a mysterious, pseudo selective wide scope in this case. While the actual reason behind this pseudo selective scope is unknown, what is important is

whether there are significantly more ‘correct’ responses in the KNOW condition than in the THINK condition, combining the SUBJ-WIDE and OBJ-WIDE conditions. To examine this, I employed the `glmer` function in the statistical package `lme4` in R. The data was fitted into a generalized linear mixed (logit) model using the maximum likelihood method (Laplace Approximation). The dependent variable was selection of ‘correct’ and ‘incorrect’. Fixed effects included predicate (with two levels, i.e., KNOW vs. THINK) and scope pattern (with two levels, SUBJ-WIDE vs. OBJ-WIDE), as well as the interaction between predicate and scope pattern. Participants and scenarios were entered as random effects. Results are in Table 2. The model shows significant effects of the Predicate condition ($p < 0.001$).

	β	SE	z	p
(Intercept)	-1.0574	0.4014	-2.634	0.00843 **
PredicateThink	-1.4961	0.5130	-2.916	0.00354 **
ScpPatternObj-Wide	-0.1372	0.4194	-0.316	0.75164
PredicateThink:ScpPatternObj-Wide	0.6478	0.6618	0.979	0.32765

Table 2: Results of the model testing the effect of the Predicate condition in native speakers’ judgments of the selective wide scope reading. Model was fitted using maximum-likelihood estimation (Laplace approximation) and used a binomial logarithmic likelihood function. Formula: `Judgement ~ Predicate*ScpPattern + (1 | Participant) + (1 | Scenario)`.

This suggests that the predicate type makes a difference for the selective wide scope behavior of embedded *wh*-phrases. Since the KNOW condition allows selective wide scope while the THINK condition does not, we then can infer that it is the availability of the selective wide scope interpretation that has led to proportionally more ‘correct’ responses in the KNOW condition.

Secondly, selective scope is not dis-preferred regardless of the syntactic position of the *wh*-phrase. To wit, only 34.2% of the responses in the SUBJ-WIDE condition and 31.5% of the responses in the OBJ-WIDE condition actually supported the selective wide scope reading when the predicate was *zhidao* ‘know’. What this means is that more than 60% of the participants judged the KNOW condition in a SUBJ-WIDE or OBJ-WIDE scenario ‘incorrect’, indicating that they rejected the selective wide scope interpretation.

Thirdly, according to Figure 5, although there were slightly more ‘correct’ responses in the SUBJ-WIDE condition (34.2%; raw number = 25) than in the OBJ-WIDE condition (31.5%; raw number = 23), suggesting that a subject *wh*-phrase might be more adept in taking selective wide scope, the difference is actually not statistically significant according to Table 2 ($p > 0.05$; cf. Experiment 2, which shows a more pronounced subject-object asymmetry).

Since Figure 5 categorizes the responses rather than the participants, it is worthwhile to consider two more figures (Figures 6a and 6b), which summarize, for the SUBJ-WIDE and OBJ-WIDE condition respectively, how each participant performed in the target and baseline condition.

To assess how each participant performed across items, we conducted an individual analysis. Although there were not many items for each condition, it is still possible to assign the participants to groups and look for patterns. Figure 6a shows, for the SUBJ-WIDE condition, how frequent a particular combination of responses is in the target and baseline condition. The most frequent combination is for a participant to assign ‘incorrect’ to both the THINK condition and the KNOW

condition (represented as ‘Think0Know0’) (40 out of 73 participants). These responses correspond to the narrow scope reading of *wh*-phrases. There are 17 participants who assigned ‘correct’ to the KNOW condition (represented as ‘Know1’), but ‘incorrect’ to the THINK condition (represented as ‘Think0’). Their responses show that selective scope interpretation is possible for at least some of the native speakers. Interestingly, some of the participants responded unexpectedly for the baseline condition as they assigned ‘correct’ to the THINK condition. These participants are divided into two groups. One group (8 participants) also chose ‘correct’ for the KNOW condition, but the other group (8 participants) chose ‘incorrect’ for it. It is not clear, based on this figure alone, why these two groups of participants existed. However, even if we regard the ‘Know0Think1’ and ‘Know1Think1’ combinations as pure noise, the fact that the ‘Know1Think0’ combination outnumbers these two combinations more than twice suggests that this combination is above the noise level.

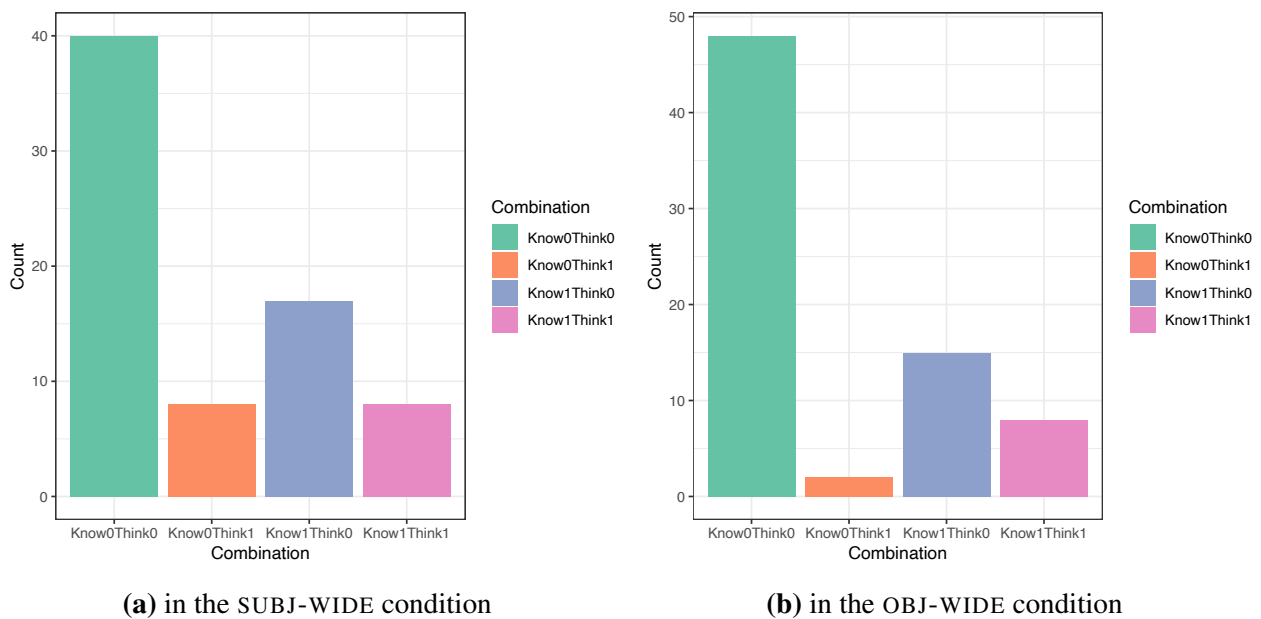


Figure 6: Distribution of participants

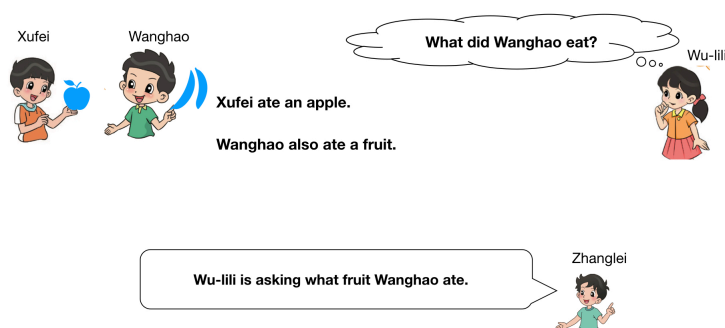
Turning to the OBJ-WIDE condition in Figure 6b, we see a similar distribution of the response combinations. Almost two thirds of participants (48 out of 73) assigned ‘incorrect’ to both the KNOW condition and the THINK condition (i.e., producing the ‘Know0Think0’ combination), making this combination the most frequent one among the four combinations. The next most frequent combination is for participants who assigned ‘incorrect’ to the THINK condition but ‘correct’ to the KNOW condition (‘Know1Think0’), account for about one fifth of the participants (15 out of 73). The difference in terms of frequency between the ‘Know0Think1’ combination and the ‘Know0Think0’ combination suggests that most participants prefer the narrow scope interpretation of a *wh*-phrase to its selective wide scope interpretation. However, despite being preferred by only a small proportion of the participants, the fact that this combination still outnumbered the other two combinations with unexpected responses on the baseline items (2 and 8 out of 73, respectively) suggests that this group of participants were not just randomly choosing this particular combination.

In conclusion, the results of this experiment suggest that it is possible for *wh*-phrases to selectively take scope over a question-selecting verb. However, the selective wide scope interpretation is not preferred.

4 Experiment 2

4.1 Design and materials

The materials used in Experiment 2 were the same as those used in Experiment 1, except for the scale used for judging the ‘correctness’ of the test sentences. Recall that a binary scale was used in Experiment 1 for judging whether a sentence was ‘correct’ or ‘incorrect’ in a certain scenario. In Experiment 2, instead of a binary scale, a 5-point Likert scale was used. The minimum point on the scale was ‘0’ (completely incorrect), and the maximum was ‘4’ (completely correct.) A participant was free to choose between any point between 0 and 4, down to a decimal place. The intermediate points 1, 2, and 3 were labeled as ‘basically incorrect’, ‘marginally correct’, and ‘basically correct.’ The instruction of the task was also slightly modified: instead of asking a participant whether a sentence was correct in capturing a scenario, it asked the participant whether a sentence can be used to capture the scenario. A sample task in Experiment 2 is given in Figure 7.



According to the scenario consisting of pictures and texts, can the following sentence be correctly used to describe the scenario?

Zhanglei zhidao Wu-lili xiang wen shei chi-le shenme shuiguo.
 Zhanglei know Wu-lili want ask who eat-Asp what fruit

0	1	2	3	4
Completely correct	Basically correct	Marginally correct	basically correct	Completely correct

Figure 7: A sample target item in Experiment 2

4.2 Participants

Like that for Experiment 1, the participants for Experiment 2 were college students from various universities in China recruited with the generous help of their course instructors. A total of 109 surveys were collected from the participants, with help of the online survey platform Qualtrics. All participants volunteered to participate in the experiment and received no compensation. Since Experiment 1 and Experiment 2 were advertised with help of different instructors teaching in different universities, it is unlikely that any participant attempted both experiments.

4.3 Results and discussion

Among the 109 surveys, only 93 were complete and hence included for data analysis. These 93 surveys were subject to further screening by the control conditions. The PRES control and the SCOPE control together excluded 21 participants and the NS control further excluded 10 participants, leaving data points from 62 participants for data analysis.

The results from Experiment 2 basically echoed the results from Experiment 1, indicating the validity of Experiment 1. However, because of the use of a continuous scale for judging correctness, some of the patterns were more pronounced in Experiment 2 than in Experiment 1. The results from Experiment 2 are discussed in the following paragraphs.

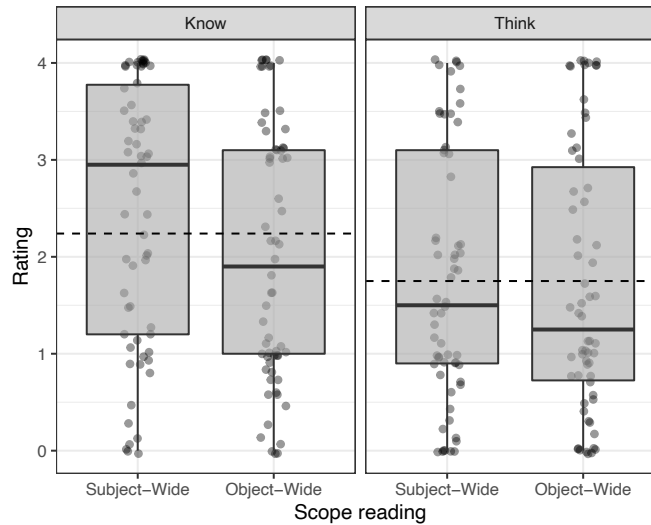


Figure 8: Descriptive statistics for Experiment 2

Consider the boxplots in Figure 8. The two panels illustrate the distribution of ratings for the KNOW condition and the THINK condition in the SUBJ-WIDE and OBJ-WIDE conditions. The dash lines indicate group means, which is 2.24 for the KNOW condition and 1.75 for the THINK condition. The low rating for the THINK condition holds uniformly for the SUBJ-WIDE condition and the OBJ-WIDE condition. This is expected because *renwei* ‘think’ does not support selective scope taking of embedded *wh*-phrases in any position. The mean rating for the KNOW condition is higher than that of the THINK condition, with the mean rating of the SUBJ-WIDE condition seemingly higher than that of the OBJ-WIDE condition.

To confirm whether predicate and scope pattern plays significant roles in determining the rating of the stimuli, I fitted a linear mixed effects model to the data using the maximum likelihood method and Satterthwaite’s method for t-test. The dependent variable was the ratings. Fixed effects were predicate, scope pattern and their interaction. Participants and scenarios were entered as random effects with random slopes for relevant factors. The result is shown in Table 3. The model suggested that the effect of predicate was significant ($p < 0.001$). In addition, the effect of scope pattern is also significant ($p < 0.05$), although less so than predicate. Lastly, the interaction between predicate and scope position is not significant ($p = 0.19$).

	β	SE	df	t	p
(Intercept)	2.4568	0.1620	77.9832	15.168	< 0.001
PredicateThink	-0.6781	0.2010	181.2973	-3.373	0.000908 **
ScpPatternObject-Wide	-0.4327	0.2070	37.0425	-2.112	0.041489 *
PredicateThink:ScpPatternObject-Wide	0.3731	0.2840	183.1284	1.313	0.190666

Table 3: Results of the model testing the effect of the Predicate and Position conditions in native speakers’ judgements of the selective wide scope reading. Model was fitted by maximum-likelihood and t-test uses Satterthwaite’s method. Formula: Judgement \sim Predicate*ScpPattern + (1 + Predicate + ScpPattern | Participant) + (1 + ScpPattern | Scenario).

Recall that in Experiment 1, scope pattern is not significant in determining the judgment of the target sentences. However, in Experiment 2, this effect reached significance. The only difference in terms of experimental design between the two experiments was in the nature of the dependent variable. In Experiment 1, judgment was a categorical variable, ranging over only two values, ‘correct’ and ‘incorrect’; whereas in Experiment 2, judgment was a continuous variable, ranging over points on a 5-point Likert scale. Another difference, not related to experimental design, was that Experiment 2 ended up yielding slightly fewer participants and data points for analysis than Experiment 1. It was well known that continuous variables encode more information than categorical variables even with smaller samples, I suspect that Experiment 2 had an advantage for detecting the effect of scope position because of the use of a continuous dependent variable. With a categorical dependent variable like the one used in Experiment 1, a lot more data points may be needed for this effect to reach significance. The effect of predicate offers partial support for this explanation: although this effect is significant in both experiments, it is much stronger in Experiment 2 than in Experiment 1, as reflected by the difference in the z score for Experiment 1 (i.e., 2.634) and t score for Experiment 2 (i.e., 3.373), as well as the difference in the relevant p values.

It is worthwhile to probe the individual variations among the 62 participants. Two scatterplots are given in Figures 9a and 9b for this purpose, one for the SUBJ-WIDE condition and the other for the OBJ-WIDE condition. The figures show how each participant rated the stimuli in the THINK condition and the KNOW condition. Each dot in the figures corresponds to a participant. The x-axis represents how the participant rated the THINK-condition and the y-axis represents how the participant rated the KNOW-condition.

The distribution of the participants is most obvious when the scatterplots were converted to the respective kernel density estimations. Kernel density estimation computes, based on some distribution, the likelihood of data points showing up in a neighborhood. This method is useful

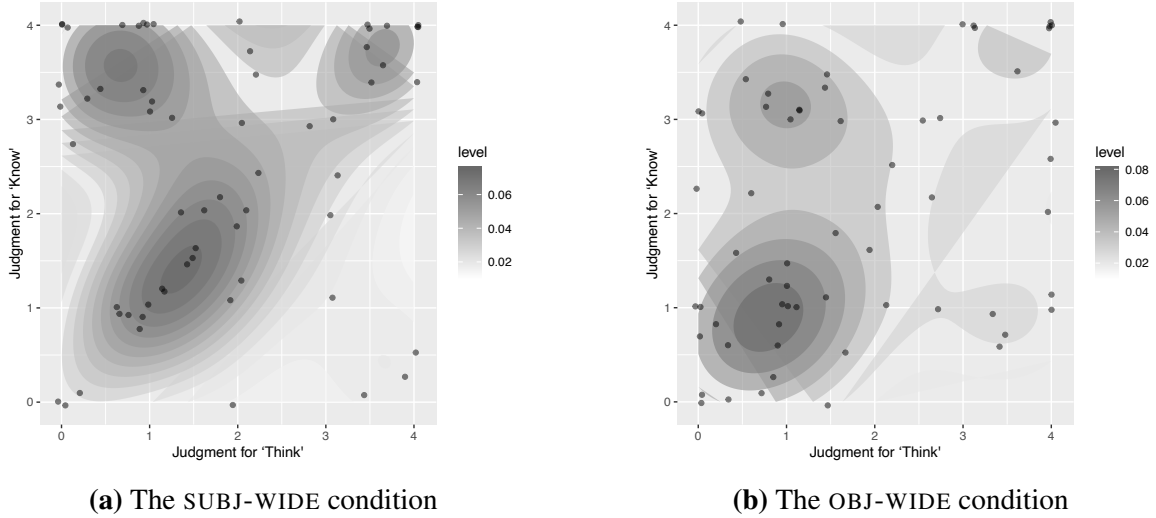


Figure 9: Scatterplots with 2d kernel density estimations

for data smoothing and drawing inferences about the population. An important note is that these estimations do not represent the actual distribution of the participants in an experiment, but an estimation of how the population would be like given the actual distribution. Despite this, I will continue to talk about ‘participants in the experiment’ rather than ‘the population’ so as to keep our focus on the participant performance.

Figure 9a, the 2d kernel density estimation for the SUBJ-WIDE condition, shows three cores, suggesting that the participants can be roughly divided into three groups. The core with the highest density appears in the lower left corner, indicating that the dominant group did not like the THINK condition or the KNOW condition in scenarios supporting the selective wide scope interpretation of a subject *wh*-phrase. Recall that the THINK condition has *renwei* ‘think’ as the matrix predicate and hence does not take a question complement. For this reason, it does not support selective wide scope taking of a subject *wh*-phrase out of the lower predicate and hence the low rating is expected. By contrast, the KNOW condition has *zhidao* ‘know’ as the matrix predicate and hence could take a question complement created by selectively letting the subject *wh*-phrase scope out of the lower predicate. The fact the dominant group assigned low ratings to the KNOW condition suggests that selective wide scope taking of a subject *wh*-phrase was unacceptable to the majority of the participants.

That being said, selective wide scope was still accepted by a less populous group of participants, as indicated by the less dense core in the upper left corner. This group of participants assigned low ratings to the baseline, THINK condition, as expected, but they assigned high ratings to the target, KNOW condition.

There is a third, even smaller group of participants, indicated by the core in the upper right corner, who gave high ratings to the THINK condition and the KNOW condition. There are a few possibilities why this group of population existed at all. One possibility is that this group of people were overly generous in rating assignment, even for sentences used incorrectly. This is compatible with the absence of a core in the lower right corner, as generous participants are usually more common than stingy participants, due to the cooperative nature of human language users. Another

possibility is that they might have misunderstood the meaning of THINK in the task, taking it to mean something like ‘having a thought about (the answer to) the embedded question,’ or simply mistaking it to be *zhidao* ‘know’. This would grant *renwei* ‘think’ the ability to take a question complement and hence potentially trigger selective wide scope taking. This possibility is also compatible with the absence of a core in the lower right corner. After all, if *renwei* ‘think’ is just another verb similar to *zhidao* ‘know’, the two verbs should not differ as to whether a *wh*-phrase inside an embedded clause can take selective wide scope. With Figure 9a alone, it’s hard to tell which possibility is more plausible. However, a look at Figure 9b shows that the second possibility is more tenable.

Figure 9b shows two cores, indicating that the participants can be categorized into two groups for the OBJ-WIDE condition. The first group is characterized by low ratings for both the THINK and KNOW condition, just like the dominant group in the SUBJ-WIDE condition, suggesting that most participants didn’t like assigning selective wide scope to an object *wh*-phrase. The second core also mimics the second core in the SUBJ-WIDE condition, showing up in the upper left corner. The presence of this core suggests that despite the less preferred status of an object *wh*-phrase taking selective wide scope, it is still available to a small subset of the participants.

Unlike the SUBJ-WIDE condition, whose kernel density estimation in Figure 9a suggests a third core in the upper right corner, no such core exists in the density estimation of the OBJ-WIDE condition. Recall the two possibilities raised for accounting for the presence of the third core in the SUBJ-WIDE condition: (i) the participants being overly generous, and (ii) mistaking *renwei* ‘think’ to be a question taking predicate. If the participants were just overly generous, we should expect them to be generous in both the SUBJ-WIDE condition and the OBJ-WIDE condition, and hence a core is expected in the OBJ-WIDE condition similar to the third core in the SUBJ-WIDE condition. The absence of this core in the OBJ-WIDE condition suggests that the third core in the SUBJ-WIDE condition was not due to a group of generous participants. The second possibility, however, is a tenable one, as long as we take into consideration a potential subject-object asymmetry in selective scope taking. All we need to assume is that a *wh*-phrase in the subject position has an easier time taking selective wide scope than that in the object position, as suggested by the different ratings for the SUBJ-WIDE condition and the OBJ-WIDE condition in Figure 8. With this assumption, we can explain the absence of the third core in the OBJ-WIDE condition like this. Despite that a group of participants mistook *renwei* ‘think’ to be a question-selecting verb, they did not prefer the selective wide scope reading of an object *wh*-phrase anyway, so they assigned low ratings to both the THINK condition and the KNOW condition. In a sense, the third core had ‘migrated’ from the upper right corner to the lower left corner due to the less acceptable nature of object *wh*-phrases taking selective wide scope.

In conclusion, Experiment 2 basically confirms the results of Experiment 1: the selective wide scope reading is possible but not preferred. Additionally, a subject-object asymmetry of selective wide scope taking was detected in Experiment 2. The results show that there was a group of native speakers who assigned selective wide scope to subject *wh*-phrases, but not object *wh*-phrases.

5 General discussion and outlook

The results of Experiment 1 and 2 were largely in consonance with Huang’s (1982a; 1982b) observation and support the scope taking approach, which assumes that *wh*-phrases are able to take

scope. As discussed in Section 2, there are two scope positions for in-situ *wh*-phrases in a KNOW type sentence, as indicated by the gaps in (19). If the two *wh*-phrases in the embedded clause can take scope, either of the gaps is a potential scope position for either of the *wh*-phrases.

(19) Subject **know** ____ Subject **ask** ____ [... WH ... WH ...]

By contrast, a THINK type sentence has only one scope position for in-situ *wh*-phrases, as illustrated in (20). This is because the verb *think* does not select a question as argument. If either of the *wh*-phrases in (20) scoped beyond *ask* but under *think*, the embedded clause of *think* would have a question denotation.

(20) Subject **think** Subject **ask** ____ [... WH ... WH ...]

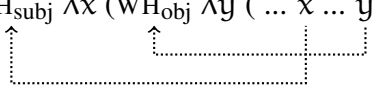
The scope taking approach allows either of the *wh*-phrases in (19) to take scope at the higher gap position in (19), but not in (20). This difference is responsible for more ‘correct’ responses in Experiment 1, and higher ratings in Experiment 2, for the target, KNOW condition.

The set-expansion approach faces more challenges than the scope-taking approach. This approach does not expect the contrast between the KNOW and THINK condition. In the set-expansion approach, none of the *wh*-phrases in (19) may take scope beyond *ask* (see Section 2), just like the *wh*-phrases in the THINK condition. Hence, in the two experiments, the participants should perform in the same way when judging the KNOW and THINK conditions. This is contrary to the results of the experiments.

Although the scope taking approach predicts the possibility that in-situ *wh*-phrases selectively take wide scope, this approach itself does not account for two preferences observed in the two experiments. First, the narrow scope interpretation, instead of the selective wide scope interpretation, is preferred. The difference between these two interpretations is very significant. In order to capture this fact, we have to consider scope islands. Cross-linguistically, embedded interrogative clauses are known to be scope islands for *wh*-phrases (Dayal 1996). For example, in (19), the clause complement of *ask* can be seen as a scope island for either *wh*-phrase. Consequently, the scope island tends to prevent the in-situ *wh*-phrases from scoping beyond it.

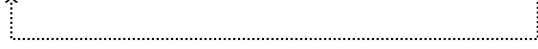
Nevertheless, it does not mean that the *wh*-phrases are impossible to escape the island. In the scope taking approach, it has been assumed that islands are able to take scope themselves. Based on this assumption, Fiengo et al. (1988), Dayal (1996) and Charlow (to appear) each have proposed a mechanism to let *wh*-phrases scope out of islands. According to Charlow, whose proposal is the closest to Karttunen’s approach, the two *wh*-phrases in (19) take scope within the embedded interrogative clause, leading to two layers of *wh*-scope, as in (22)⁴; then the whole embedded clause scopes over the verb *ask*, as in (21-b); in the end, the inner layer semantically reconstructs to within the scope of *ask* (see also Cresti 1995), as in (21-c).

(21) a. Subject **know** ____ Subject **ask** [WH_{subj} λx (WH_{obj} λy (... x ... y ...))]

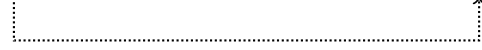


⁴It should be noted that even if we assume in the set expansion approach that islands can take scope, the selective wide scope reading is still impossible to derive. This is because the proposed analysis in (21) has to let the in-situ *wh*-phrases take scope within the island first. Otherwise, the two scope layers cannot be derived, and hence the object *wh*-phrase cannot be reconstructed.

b. Subject **know** [WH_{subj} λx (WH_{obj} λy (... x ... y ...))] λQ. (Subject **ask** Q)



c. Subject **know** [WH_{subj} λx (WH_{obj} λy (... x ... y ...))] λQ. (Subject **ask** Q)

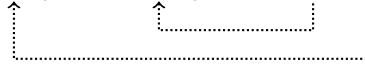


As a result, WH_{subj} scopes above *ask*, while WH_{obj} scopes under *ask*. The whole process is much more complex than scope taking without islands. The complexity of this composition may require native speakers to make an effort to generate the selective wide scope interpretation. In contrast, the narrow scope reading does not require one to overcome the island effect, so it is easier to generate. Since all the test sentences allow the narrow scope interpretation, the participants might prefer an easier parse of the target sentences, hence favoring the narrow scope interpretation over the selective wide scope interpretation⁵.

Although the effect of predicate was clear in the two experiments, the effect of scope pattern was less so. For one thing, a subject-object asymmetry was only detected in Experiment 2. For another thing, even if we take the effect found in Experiment 2 as representative, we still need to gain more understanding of the nature of the asymmetry. In particular, we do not have conclusive evidence at this point suggesting whether the asymmetry is due to a grammatical effect, an extra-grammatical effect, or a combination of both. In what follows, I explore a grammatical explanation and an extra-grammatical explanation for the asymmetry. The goal of the discussion is more to help direct future research than to adequately account for the asymmetry.

A grammatical perspective is to reduce the asymmetry to superiority effect in syntax, assuming QR obeys syntactic locality constraints like Shortest Move (Bruening 2001.) Turning back to (21), the necessary condition of the selective wide scope reading of the object *wh*-phrase is that it takes scope over the subject *wh*-phrase at the first step, as shown in . However, raising the object *wh*-phrase beyond the subject *wh*-phrase violates Shortest Move.

(22) Subject **know** ____ Subject **ask** [WH_{obj} λy (WH_{subj} λx (... x ... y ...))]



⁵Moltmann & Szabolcsi (1993) use almost the same way to analyze a ‘clause-crossing’ pair list reading of (i). In the reading, the universal quantifier scopes out of the clause island, quantifying into the *wh*-question. It seems that the universal quantifier selectively take wide scope. However, native speakers do not have difficulties to get this reading.

- (i) Some librarian or other found out which book every student needed.
 ~> ‘For every student, there is a librarian who found out which book she needed.’

I conjecture that *wh*-phrases differ from universal quantifiers in that the former are much harder to take the selective wide scope. This is also supported by Moltmann & Szabolcsi’s observation: the ‘clause-crossing’ pair list reading becomes impossible when the universal quantifier in (i) is replaced with a *wh*-phrase, as shown below.

- (ii) Some librarian or other found out which student needed which book.
 ~> #‘For every student, there is some librarian who found out which book she needed.’

Since the comparison of quantifiers and *wh*-phrases is beyond the scope of the paper, I leave this issue for future studies.

An extra-grammatical perspective is to invoke processing to account for the subject-object asymmetry. Specifically the asymmetry may be a result of a left-to-right bias of processing. Usually, a scope-bearing element processed earlier takes wider scope. Hence, a subject *wh*-phrase is easier to take selective wide scope than an object *wh*-phrase.

Lastly, I have to admit that the two experiments may have underestimated native speakers' knowledge of selective wide scope in more than one way. To begin with, if the reasoning on the preference of the narrow scope reading is on the right track, the presence of the narrow scope reading may have a negative effect on participants' preference for selective wide scope. In order to address this potential problem, I suggest a further study in which the two embedding verbs are changed to ones obligatorily selecting questions. In particular, the first verb can be *wen* 'ask', while the second one can be *xiangzhidao* 'wonder', as illustrated in (23).

- (23) Zhanglei zai wen Wu-lili xiangzhidao shei chi-le shenme shuiguo.
 Zhanglei Prog. ask Wu-lili wonder who eat-Asp what fruit
 a. Zhanglei is asking who is the person such that Wu-lili wonders she ate what fruit.
 b. Zhanglei is asking what is the fruit such that Wu-lili wonders who ate it.
 c. *Zhanglei is asking Wu-lili wonders who ate what fruit.

This sentence forces the selective wide scope reading for the in-situ *wh*-phrases. Both *wen* 'ask' and *xiangzhidao* 'wonder' must select a question. Therefore, one of the *wh*-phrases in (23) has to take scope over *xiangzhidao* but under *wen*, while the other must take scope under *xiangzhidao*, giving rise to the readings in (23-a) and (23-b). If both *wh*-phrases take narrow scope, like (23-c), the argument of *wen* 'ask' won't be a question. This reading should not be possible.

The set expansion approach and the scope taking approach makes different predictions for sentences like (23): the former expects them to be unacceptable, since the selective scope reading is not possible in this approach; whereas the latter expects them to be acceptable. We can ask native speakers to judge the acceptability of sentences like (23) based on a Likert scale, as done in Experiment 2. They should give relatively high ratings to the sentences if the scope-taking approach offers the right compositional mechanism, and lower ratings if the set-expansion approach is the right one.

Moreover, as pointed out by Anna Szabolcsi (p.c.), replacing the *wh*-phrases in the test sentences with D-linked *wh*-phrases, like *na-xie shuiguo* 'which fruits', may improve the acceptability of the selective wide scope reading. D-linked *wh*-phrases require its domain to be specific in the context, and generally specificity facilitates wide scope interpretations. Therefore, we should take this factor into consideration when designing future experiments to probe the selective wide scope potential of *wh*-phrases.

6 Conclusion

This study investigated the selective wide scope potential of interrogative *wh*-phrases in Mandarin. The results from two experimental studies unanimously point to the reality of selective wide scope, despite it being a difficult-to-access reading and only accepted by a subset of the participants. The finding is used to argue for a scope-taking approach to *wh*-question composition over a set-expansion approach.

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