

Deriving short answers from dynamicized Hamblin sets: Arguments from Mandarin *wh*-conditionals*

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Abstract Short answers to *wh*-questions cannot be derived from the Hamblin/Karttunen (H/K) denotations of questions, which are sets of propositions, i.e., Hamblin sets. However, such a derivation is possible if the structure of a proposition is enriched. In this paper, I argue that the sentential denotation in dynamic semantics has enough structure to support the retrieval of short answers from full answers. Specifically, *wh*-expressions make dynamic discourse contributions: they introduce discourse referents (drefs), as evidenced by their ability to support cross-sentential anaphora. Correspondingly, a *wh*-question denotes a set of *dynamic* propositions. The drefs can be retrieved to model short answers. In addition to proposing a new way for deriving short answers, this paper demonstrates the usefulness of the analysis in connection with a non-canonical *wh*-construction in Mandarin known as *wh*-conditionals. In particular, I analyze *wh*-conditionals as quantification over short answers derived from dynamicized Hamblin sets. This approach to *wh*-conditionals is compared with previous studies based on the categorial approach and is argued to be more adequate.

Keywords: *wh*-conditionals, short answers, dynamic semantics, discourse referents

1 Introduction

A *wh*-question like (1)-A may admit two types of answers: a *full* answer identifying the individual in the form of a sentence, as in (1)-B-i, or a *short*, fragment just naming the individual, as in (1)-B-ii.

(1) A: Who was late? B: (i) Ann was late. (ii) Ann.

It is an on-going debate whether a short answer is independently represented in the semantic component or derived from the full answer via syntactic ellipsis. Recently,

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a number of studies have argued that the semantics of at least some *wh*-constructions is built on short answers. For example, Chierchia & Caponigro (2013) and Xiang (2016) propose that (2-a) roughly has the meaning specified in (2-b), where the underlined part corresponds to a short answer.

- (2) a. We hired who Ann voted for.
 b. We hired x and x is the short answer to the question *who Ann voted for*

On this view, free relatives are derived from ordinary *wh*-questions via the short answer representation, allowing a uniform analysis of *wh*-questions and free relatives.

Two approaches have been proposed to generate short answers from questions. The first one assumes a Hamblin/Karttunen (H/K) semantics, which takes a *wh*-question to denote a set of propositions. For example, assuming two relevant individuals *Ann* and *Eric* in the model, the question *who was late* denotes the set in (3), which has two sets of possible worlds. I follow the literature and refer to such a set as a ‘Hamblin set’.

- (3) $\{\{w \mid \text{Ann was late in } w\}, \{w \mid \text{Eric was late in } w\}\}$

To model a short answer, this approach needs a way to retrieve *Ann* and *Eric* from (3). However, as pointed out in Zimmermann (1985) and Groenendijk & Stokhof (1989), it is impossible to extract individuals from sets of possible worlds, as one cannot reconstruct the compositional history that gives rise to a set of possible worlds. To put simply, the possible worlds in the set $\{w \mid \text{Ann was late in } w\}$ may also verify the sentence *Ann and Bob didn't attend the class*, but *Ann and Bob* isn't included as a possible short answer, according to (3)¹.

The second approach relies on the categorial approach (Hausser & Zaefferer 1979; von Stechow & Zimmerman 1984; Ginzburg & Sag 2000; a.o.), which defines questions as so-called *abstracts*². The question *who was late* denotes a function in (4). ‘ w_0 ’ refers to the actual world throughout the paper. The abstract characterizes a set of individual–world pairs $\langle x, w \rangle$ such that x is a human in w_0 and was late in w .

- (4) $\lambda x \lambda w. \text{human}_{w_0}(x) \wedge \text{late}_w(x)$

Short answers can be easily derived in this approach (Groenendijk & Stokhof 1989; Jacobson 2016). The short answer to *who was late* is the person that saturates the first argument of the abstract in (4), leading to a true proposition in the actual world.

Although the H/K semantics is indeed unable to derive short answers under the

1 Zimmermann (1985) has formally prove that it's impossible to retrieve a short answer from the corresponding propositional answer. The original argument is directed at Groenendijk & Stokhof's (1984) partition semantics of questions, but it carries over to any account based on the Hamblin set.

2 The terminology is credited to Groenendijk & Stokhof (1982).

assumption that full answers denote sets of possible worlds, this may not be the case when the denotation of a sentence has more structure than a set of possible worlds. In fact, once the sentential denotation has a structure that makes the contribution of *wh*-expressions accessible, the derivation of short answers from full answers becomes possible. This paper proposes a specific way for achieving a more structured proposition—by dynamicizing the H/K semantics. In particular, *wh*-expressions denote a set of *dynamic* proper names, each of which introduce a discourse referent (dref), and correspondingly, *wh*-questions denote sets of *dynamic* propositions, i.e., dynamicized Hamblin sets. Dynamic propositions involve more information than static ones. The former not only express propositional contents but also record drefs. For a *wh*-question Q , each member in the dynamicized Hamblin set denoted by Q is associated with a dref introduced by the *wh*-expression. The drefs can be retrieved from the dynamic Hamblin set and they are precisely the set of possible short answers to Q . Thus, dynamic propositions have enough structure to support the retrieval of short answers from full answers.

In addition to offering a novel way for deriving short answers, this paper takes up *wh*-conditionals in Mandarin and shows that the dynamic approach is empirically more adequate than the categorial approach. Specifically, I argue that Mandarin *wh*-conditionals are analyzed as quantification over short answers (cf. Liu 2016; Xiang 2016). Although the categorial approach can also generate short answers, it faces general compositional challenges, as pointed out in Groenendijk & Stokhof (1989), which become even harder in the environment of *wh*-conditionals. By contrast, the dynamic approach that I propose is built on the H/K semantics, so it inherits all the compositional merits of the latter.

This paper is organized as follows: Section 2 sketches a question approach to Mandarin *wh*-conditionals. In this approach, short answers are the crucial factor to formalize the meaning of *wh*-conditionals. Section 3 shows that the derivation of short answers based on the categorial approach faces non-trivial problems when explaining *wh*-conditionals. Section 4 lays out my proposal—a dynamic semantics of *wh*-questions and shows how short answers are derived from dynamic Hamblin sets. Section 5 shows that the present analysis avoids the problems that the categorial approach has. Section 6 concludes.

2 Short answers and Mandarin *wh*-conditionals

In Mandarin, a conditional can connect two *wh*-clauses, as in (5), which can be translated as English *wh-ever* conditionals. (5) is a conditional not only because of its meaning, but also because it contains a conditional marker *jiù*, which is obligatory in ordinary conditional sentences such as (6). Because of the combination of the *wh*-clauses and the conditional morphology, sentences like (5) are called

wh-conditionals.

- (5) Shéi^x chídào, shéi^x jiù shòufá.
 who late who then be.penalized
 ‘Whoever is late, they will be the ones that are penalized.’
- (6) Lǐbái chídào, tā jiù shòufá.
 Libai late he then be.penalized
 ‘If Libai is late, he’ll be penalized.’

An intriguing property of *wh*-conditionals is that the *wh*-expression in the consequent *must* be anaphoric to the *wh*-expression in the antecedent, as indicated by the same index that the two *wh*-expressions bear in (5).

Recently, Liu (2016) and Xiang (2016) have argued that *wh*-conditionals embed two *wh*-questions and express the dependency between the questions regarding the short answers to them³. Concretely, (5) implies that the short answer to the question *who’s late* is also the short answer to the question *who will be penalized*. As a result, it’s indicated that the ones who are late are the ones who will be penalized. The apparent coreference of the two *wh*-expressions are forced by the question dependency relative to short answers.

In this paper, I promote this question approach to *wh*-conditionals. Specifically, I propose that a *wh*-conditional consists of two *wh*-questions and its meaning is formalized as quantification over short answers to the *wh*-questions. The interpretation of *wh*-conditionals is compositionally built on the semantics of conditionals. I assume a short answer retrieving operator **SA** that takes a *wh*-question and returns a set of possible short answers to it. **SA** is informally defined in (7). The formal definition is given in Section 4.3.

- (7) **SA**([[Q]]) := $\lambda x \lambda w. x$ is the short answer to Q in *w*

Following the LKH approach, *wh*-conditionals as a type of conditionals also give rise to quantificational structures (see also Cheng & Huang 1996; Lin 1996; Chierchia 2001): the *wh*-antecedents serve as the restrictions of quantificational operators, while the *wh*-consequents the scopes of the operators. For example, the meaning of *wh*-conditionals without overt quantificational adverbs/modals is informally represented as (8).

- (8) [[Q₁ jiù Q₂]] = ALWAYS_{x,s} [SA([[Q₁]])(x)(s)] (SA([[Q₂]])(x)(s))

Generally, ALWAYS quantifies over situations *s*. In this paper, I consider a situation

³ Liu (2016) offers many empirical arguments against the classical ‘donkey’ analysis (Cheng & Huang (1996)) and the correlative analysis (Huang 2010; Luo & Crain 2011). Due to the limitation of space, I refer the reader to Chapter 5 of Liu’s (2016) dissertation.

part of a possible world (Kratzer 1989) and simply assume that situations are in the same domain as possible worlds. Moreover, quantificational adverbs like *ALWAYS* are polyadic quantifiers (Chierchia 1992). They can unselectively bind any other variables in the restriction and scope. In Section 4.4, I'll show how the representation in (8) is formally implemented in dynamic semantics.

Both Liu (2016) and Xiang (2016) also formalize the meaning of *wh*-conditionals with the use of short answers, but their analyses differ from mine in a crucial respect—the derivation of short answers. Xiang's analysis employs the categorial approach, while Liu's the structured meaning approach. Although their implementations are not the same, they share the assumption that the meaning of *wh*-questions involves abstracts in terms of the categorial approach. In the next section, I'll show that deriving short answers based on abstracts cannot adequately account for *wh*-conditionals.

3 Issues of deriving short answers

Although the question approach can cover many empirical facts of *wh*-conditionals, it still faces a crucial challenge, i.e., finding a way to derive short answers. The categorial approach indeed has an advantage in the derivation of short answers, but also suffers from compositional problems when deriving question meaning (Groenendijk & Stokhof 1989; George 2011). In the question approach, the *wh*-clauses in a *wh*-conditional are considered questions. If the categorial approach is employed to derive short answers, similar problems also arise in the derivation of *wh*-conditionals and become even harder. Specifically, for *wh*-conditionals, the categorial approach is too weak on one hand, since it cannot account for the fact that *wh*-conditionals can embed coordinations of *wh*-clauses; it's also too strong on the other hand, since it wrongly allows the conditional to embed polar questions.

3.1 Coordination of *wh*-clauses in *wh*-conditionals

The categorial approach always has a difficulty in capturing coordination of *wh*-questions (*wh*-coordination). Consider the example in (9).

(9) Who did you marry and where did you live?

In the categorial approach, the abstracts denoted by the *wh*-conjuncts are properties, which are often conjoined by Predicate Modification, as in (10). The result is also a property. Whatever individuals that have this property are both human and places. This is impossible.

(10) $\llbracket \text{who did you marry} \rrbracket^{w_0} \sqcap \llbracket \text{where did you live} \rrbracket^{w_0}$

Deriving short answers from dynamicized Hamblin sets

$$\begin{aligned}
 &= (\lambda x \lambda w. \text{human}_{w_0} \wedge \text{marry}_w(x)(\text{hr})) \sqcap (\lambda x \lambda w. \text{place}_{w_0}(x) \wedge \text{live}(x)(\text{hr})) \\
 &= \lambda x \lambda w. \text{human}_{w_0} \wedge \text{marry}_w(x)(\text{hr}) \wedge \text{place}_{w_0}(x) \wedge \text{live}(x)(\text{hr})
 \end{aligned}$$

A worse case is the conjunction of a single-*wh* question and a multiple-*wh* question. In the categorial approach, *wh*-questions have non-uniform types. For example, *who arrived* denotes a function mapping individuals to propositions, as in (11-a), while *who bought what cake* a function mapping individuals to properties, as in (11-b).

- (11) a. $\lambda x \lambda w. \text{human}_{w_0} \wedge \text{arrive}_w(x)$
 b. $\lambda x \lambda y \lambda w. \text{human}_{w_0}(x) \wedge \text{cake}_{w_0}(y) \wedge \text{buy}_w(y)(x)$

Generally, only the constituents with the same type can be coordinated. Therefore, the coordinated constituents like **jump and look for*, **Lee and boy* and **run and Lee* are banned. The categorial approach predicts that single *wh*-questions cannot be conjoined with multiple-*wh* questions. The predication is not borne out. The coordination in (12) is acceptable.

- (12) Who arrived and who bought what cake?

The same difficulty also applies to *wh*-conditionals, which can embed *wh*-coordinations, as in (13) and (14). Note that in Mandarin clausal coordination isn't marked by an overt conjunct.

- (13) Nǐ [chī **shá**^x cài], [hē **shá**^y jiǔ], wǒ jiù yào [chī **shá**^x cài], [hē **shá**^y jiǔ].
 you eat what dish drink what wine I then must eat what dish drink what wine
 'No matter what dish you eat and what wine you drink, I must eat the same dish and drink the same wine.'
- (14) Nǐ shàngcì [tūo **shéi**^x mǎi-le **shěnmé**^y lǐwù], bìng [bǎ tā sòng-gěi-le **nǎ-gè**^z nǚshēng], wǒ zhècì jiù [tūo **shéi**^x mǎi shěnmé^y lǐwù], yě [bǎ tā sòng-gěi **nǎ-gè**^z nǚshēng].
 you last.time ask who buy-ASP what gift and BA it send-give-ASP which-CL girl I this.time then ask who buy what gift also BA it send-give which-CL girl
 'No matter who you asked to buy what gift and sent it to which girl last time, I'll ask the person to buy that gift and also send it to that girl.'

In (13), if the *wh*-coordinations were analyzed as the conjunction of two abstracts, an impossible interpretation would be generated: the speaker and the addressee would eat and drink a thing that is both a dish and a wine. In (14), both *wh*-coordinations

consist of a multiple-*wh* clause and a single *wh*-clause. Its acceptability is beyond the expectation of the categorial approach.

Wh-coordination itself doesn't cause a fatal problem for the categorial approach, because we can always shift an abstract denotation of a *wh*-question to a Hamblin set. We can define an operator π , as in (15). It takes an abstract R , which may be a function having arguments of any number (marked by \vec{x}), and returns a set of propositions (see also Berman 1991).

$$(15) \quad \pi(R) := \lambda p \exists \vec{x}. p = R(\vec{x})$$

Before two *wh*-clauses are conjoined, π applies to each of them, yielding two Hamblin sets. The two sets can be conjoined via a pointwise conjunction rule, defined as in (16).

$$(16) \quad \llbracket Q_1 \text{ and } Q_2 \rrbracket = \{ p \wedge q \mid p \in \llbracket Q_1 \rrbracket, q \in \llbracket Q_2 \rrbracket \}$$

As argued in Groenendijk & Stokhof (1989), the denotation of a *wh*-question may be flexible and the type shifting process, as instantiated by π , can unify the merits of the categorial approach and the H/K approach.

However, this flexible view of the question meaning doesn't save the categorial approach from failing to explain *wh*-conditionals. Although the π -application resolves the problem of coordination, it eliminates an important advantage of the categorial approach: once the abstract denoted by a *wh*-question is shifted to a Hamblin set, it is not possible to track the short answer to the *wh*-question anymore. As a consequence, if we employ π to derive the *wh*-coordinations embedded in the *wh*-conditionals (13) and (14), we are no longer able to get the short answer to the *wh*-coordinations. Hence, assuming the categorial approach, the question approach cannot account for these *wh*-conditionals^{4,5}.

⁴ Jacobson (2016) suggests that *wh*-questions should be coordinated in the speech act level, as proposed by Krifka (2001b). At the speech act level, the type of questions becomes uniform and coordination won't be problematic. However, the *wh*-coordinations are embedded in conditionals in (13) and (14). No evidence has been provided to show that Mandarin conditionals can embed speech acts. In addition, it's not clear whether short answers are still retrievable when *wh*-questions are transferred to speech acts.

⁵ Xiang (2016) tries to derive *wh*-coordination via type-lifting (see also Krifka 2001a). For example, the two questions in (12) are lifted and then conjoined, i.e., $\lambda Q. Q(\llbracket \text{who enters} \rrbracket) \wedge Q(\llbracket \text{who bought what cake} \rrbracket)$. Q is a function maps abstract denotations to truth values. However, this result still runs into a problem of non-uniform types. Q that applies to *who enters* has a different type from Q that applies to *who bought what cake*. They shouldn't be in the same domain. Therefore, $\lambda Q. Q(\llbracket \text{who enters} \rrbracket) \wedge Q(\llbracket \text{who bought what cake} \rrbracket)$ isn't defined.

3.2 Over-generation

Deriving the meaning of *wh*-conditionals based on the categorial approach is confronted with a potential over-generation problem. The most crucial point of the question approach is that *wh*-conditionals express a question dependency with respect to short answers. Polar questions also have short answers—*yes* and *no* (Krifka 2001a). In the categorial approach, a polar question may be analyzed as an abstract that maps functions to propositions, as exemplified in (17). The short answer to the question will be the function $\lambda p.p$, which corresponds to the affirmative response *yes*, or the function $\lambda p.W - p$ (W is the set of all the possible worlds), which corresponds to the negative response *no*. A similar analysis has been proposed in Krifka (2001a).

$$(17) \quad \llbracket \text{Did Ann leave} \rrbracket = \lambda f.f(\lambda w.\text{leave}_w(a))$$

Consequently, the question approach to *wh*-conditionals won't prevent the conditional marker *jiu* from connecting two polar questions. Specifically, the sentence in (18) should be allowed. Note that non-baise polar questions in Mandarin are marked by V-not-V forms.

$$(18) \quad *L\check{i}b\acute{a}i\ z\check{o}u\text{-}b\grave{u}\text{-}z\check{o}u, \quad D\grave{u}f\check{u}\ j\grave{i}\grave{u}\ z\check{o}u\text{-}b\grave{u}\text{-}z\check{o}u.$$

Libai leave-not-leave Dufu then leave-not-leave

The conditional would mean that whether Dufu will leave or not depends on the short answer to the question *does Libai leave*. That is, if Libai will leave, then Dufu will leave; if Libai won't leave, then Dufu won't leave. Unfortunately, Cheng & Huang (1996) have pointed out that this kind of conditionals don't exist.

4 A dynamic approach

I propose a novel way to derive short answers from Hamblin sets by appealing to dynamic semantics. The proposal relies on the assumption that *wh*-expressions introduce alternative drefs and *wh*-questions denote sets of dynamic propositions. Short answers can be derived by retrieving the drefs introduced by the *wh*-expression in a question. Once the derivation of short answers is in place, I formulate a more adequate account for *wh*-conditionals.

4.1 A dynamic semantics for *wh*-questions

It's well known that indefinites can support pronouns across sentence boundaries, as shown in (19). The cross-sentential binding phenomenon receives a straightforward account in dynamic semantics. Simply put, indefinites introduce drefs, which serve

as the discourse antecedents for pronouns occurring in the following sentences.

(19) A man^x came in. He_x sat down.

It has been observed for some time that interrogative *wh*-expressions, too, can bind pronouns across sentence boundaries (Comorovski 1996; van Rooy 1998; Haida 2007; Rawlins 2013; Dotlačil & Roelofsen 2018), as in (20). In order to answer the sequence of questions in (20), for example, the addressee must name the boy who took pictures and specify the kind of camera that boy used. Importantly, the pronoun *he* co-varies with the short answer to the first question.

(20) Which boy^x took pictures? What camera did he_x use?

In van Rooy (1998), Haida (2007) and Dotlačil & Roelofsen (2018), *wh*-expressions introduce drefs like indefinites. This naturally calls for a dynamic semantics of *wh*-questions that allows subsentential dynamic effects to license pronouns.

In addition to allowing *wh*-expressions to introduce drefs, I distinguish the drefs introduced by the *wh*-expression in a *wh*-question from the ones introduced by the other items in this question. As argued in Krifka (2001a), a *wh*-question is partitioned based on the information structural properties. The non-*wh* portion of a question is GIVEN in the sense of Schwarzschild (1999), whereas the *wh*-expression acts as the sentence focus. For instance, the question *who did Ann see* can be uttered only in the situation where the information that Ann saw someone is salient. When a focused phrase occurs in a *wh*-question, like *who only invited Ann_F*, this phrase may bear a secondary focus, instead of the primary focus. Tomioka (2007) argues that the co-occurrence of a *wh*-expression and another primary focus leads to unnaturalness.

The information status of drefs has been incorporated into dynamic semantics. In Bittner (2014) and Murray (2010, 2014), an information state (info-state) is assumed to be a pair of stacks that store various drefs (see also Dekker 1994, Nouwen 2003). Specifically, a pair of stacks consists of a top stack \top and a bottom stack \perp , as shown below.

$$\langle \top : \boxed{\dots} \boxed{a} \boxed{b} \boxed{c} , \perp : \boxed{\dots} \boxed{e} \boxed{h} \boxed{g} \rangle$$

According to Murray (2010), the top stack stores the drefs which are considered to be GIVEN or in the common ground, whereas the bottom stack stores the drefs that are not GIVEN and at-issue. Following her idea, I use these pairs to distinguish the drefs introduced by *wh*-expressions and the other drefs. For a *wh*-question, the drefs introduced by the *wh*-expression are not GIVEN and stored in \perp , while the drefs introduced by other items are all GIVEN and stored in \top (cf. Murray 2010)⁶. In

⁶ Bittner (2014) uses top stacks to represent discourse centers in the sense of the centering theory

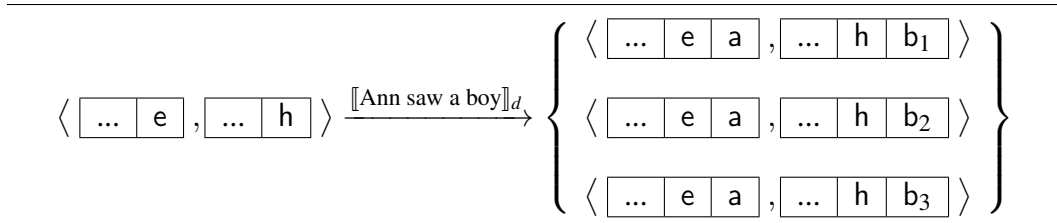


Figure 1: A sample context update

other words, relative to an info-state $\langle \top, \perp \rangle$, a *wh*-question adds to \perp only the drefs introduced by the *wh*-expression⁷.

In dynamic semantics, sentences denote *dynamic propositions*, which are devices for changing the context: fed an input information state (info-state), a sentence returns a set of updated info-states as possible outputs. Formally, dynamic propositions are intensional relations between pairs of stacks, as exemplified in (21). As $\llbracket \cdot \rrbracket$ maps a sentence into a static meaning, a dynamic interpretation function $\llbracket \cdot \rrbracket_d$ maps a sentence into a dynamic meaning.

$$(21) \quad \llbracket \text{Ann saw a boy} \rrbracket_d = \lambda_w \lambda \langle \top, \perp \rangle. \{ \langle \top \cdot a, \perp \cdot x \rangle \mid \text{boy}_w(x) \wedge \text{see}_w(x)(a) \}$$

Notations: $\langle \top, \perp \rangle$ stands for the variable of stack pairs. The stack extension operator \cdot can add an element to a stack or concatenate two stacks, visualized as follows:

$$\begin{array}{|c|c|} \hline \dots & e \\ \hline \end{array} \cdot a = \begin{array}{|c|c|c|} \hline \dots & e & a \\ \hline \end{array} \quad \begin{array}{|c|c|} \hline \dots & e \\ \hline \end{array} \cdot \begin{array}{|c|c|} \hline a & b \\ \hline \end{array} = \begin{array}{|c|c|c|c|} \hline \dots & e & a & b \\ \hline \end{array}$$

Suppose that *Ann* is GIVEN but *a boy* is informationally new. We feed the sentence in (21) the info-state $\langle \begin{array}{|c|c|} \hline \dots & e \\ \hline \end{array}, \begin{array}{|c|c|} \hline \dots & h \\ \hline \end{array} \rangle$. Then, the output is a set of stack pairs which result from adding *Ann* to the input top stack and a different boy to the input bottom stack, as visualized in Figure 1. The update is nondeterministic and the resulting set is non-singleton.

In static semantics, Hamblin (1973) proposes that the meaning of questions is a set of its possible propositional answers. *Wh*-expressions denote sets of alternatives. For example, *who* denotes a set of human entities, for instance, the set $\{ \llbracket \text{Ann} \rrbracket, \llbracket \text{Bob} \rrbracket \}$. This alternative set ‘expands’ in some compositional process and

(Grosz, Joshi & Weinstein 1995). In particular, a top stack stores drefs that are topical and in the center of attention. It should be noted that the discourse center doesn’t mean focus, but the salient and given information of a local discourse topic (Brennan 1995). So, assuming that the drefs introduced by *wh*-expressions are stored in top stacks is not incompatible with Bittner’s implementation.

⁷ Murray (2010) assumes that a *wh*-question also introduces sets of possible worlds as drefs, which are added to \perp . I don’t follow this assumption in my analysis.

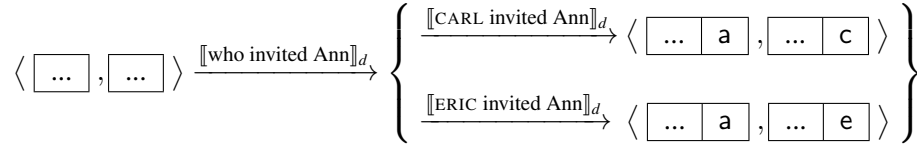


Figure 2: Discourse dynamics of *wh*-questions

finally generates a set of propositions, i.e., a Hamblin set, as the denotation of the question root.

$$(22) \quad \llbracket \text{who was late} \rrbracket = \{ \llbracket \text{Ann was late} \rrbracket, \llbracket \text{Bob was late} \rrbracket \}$$

This approach has been used to analyze many issues related to questions. The present study proposes a simple extension of this approach from a static semantics to a dynamic semantics. In a dynamic setting, a question denotes a set of dynamic propositions and a *wh*-expression denotes a set of dynamic proper names, which essentially means that it introduces (alternative) drefs. As discussed before, these drefs are added to an input \perp . Suppose that the alternative set denoted by *who* contains $\llbracket \text{CARL} \rrbracket_d$ and $\llbracket \text{ERIC} \rrbracket_d$, the *wh*-question *who invited Ann* denotes a set of dynamic propositions, as in (23). In this paper, the members in the set denoted by a *wh*-expression are written in small capital letters.

$$(23) \quad \llbracket \text{who invited Ann} \rrbracket_d = \{ \llbracket \text{CARL invited Ann} \rrbracket_d, \llbracket \text{ERIC invited Ann} \rrbracket_d \} \\ = \left\{ \begin{array}{l} \lambda w \lambda \langle \top, \perp \rangle. \{ \langle \top \cdot a, \perp \cdot c \rangle \mid \text{invite}_w(a)(c) \}, \\ \lambda w \lambda \langle \top, \perp \rangle. \{ \langle \top \cdot a, \perp \cdot e \rangle \mid \text{invite}_w(a)(e) \} \end{array} \right\}$$

Given an input context, the *wh*-question provides a set of possible context updates, as shown in Figure 2. Each of the dynamic proportions in the set (23) can update the input context and generate a possible output. The addressee has to pick out one to update the context. This mechanism follows the spirit of the discourse dynamics of questions proposed in Farkas & Bruce (2010).

The composition of the dynamic meaning of *wh*-questions is given in Appendix A. The basic question composition is borrowed from Karttunen (1977) and the basic dynamic composition from Charlow (to appear). The two semantics are synthesized with help of the compositional device proposed by Charlow's (2014, 2019, to appear). The outcome is a dynamic compositional semantics of questions in the H/K tradition.

4.2 Answerhood

It's well known that a typical *wh*-question requires the addressee to provide an exhaustive answer (Groenendijk & Stokhof 1984; Dayal 1996; Rullmann 1995; Fox 2013). In the conversation (24), the answer to A's question implies that only Ann and Bob were late.

(24) A: Who was late? B: Ann and Bob was late.

According to Dayal (1996), a number-neutral *wh*-expression like *who* can range over singular and plural individuals. The latter is formed via the summing operation \oplus (Link 1983). In the dynamic semantics of questions proposed in this study, drefs introduced by *who* may include singular individuals and their sums. Hence, the question in (24) denotes (25).

$$(25) \quad \{ \lambda w \lambda \langle \top, \perp \rangle. \{ \langle \top, \perp \cdot x \rangle \mid \text{late}_w(x) \} \mid x \in \{a, b, a \oplus b\} \} \\ = \{ \llbracket \text{ANN was late} \rrbracket_d, \llbracket \text{BOB was late} \rrbracket_d, \llbracket \text{ANN AND BOB were late} \rrbracket_d \}$$

Because of the plural individuals, I assume that the static properties and relations on which dynamic meanings are built are closed cumulatively. For example, regarding some possible world w , if $\text{late}_w(x)$ and $\text{late}_w(y)$, then $\text{late}_w(x \oplus y)$; if $\text{invite}_w(x)(y)$ and $\text{invite}_w(x')(y')$, then $\text{invite}_w(x \oplus x')(y \oplus y')$.

Dayal (1996) defines an answerhood operator that picks out from a Hamblin set the maximally informative proposition relative to a possible world. I introduce the dynamic counterpart of the answerhood operator to the dynamic semantics of *wh*-questions. Following Rullmann's (1995) terminology, the dynamicized operator is dubbed **max**:

$$(26) \quad \mathbf{max}_{w, \langle \top, \perp \rangle}(\mathcal{Q}) := \iota \phi \in \mathcal{Q}, \text{ such that} \\ \text{a. } \phi(w)(\langle \top, \perp \rangle) \text{ is dynamically true and} \\ \text{b. for all } \psi \in \mathcal{Q}, \text{ if } \psi(w)(\langle \top, \perp \rangle) \text{ is dynamically true, } \phi \text{ entails } \psi \text{ w.r.t } \langle \top, \perp \rangle$$

The dynamic truth is defined via quantification over output stack pairs, as in (27). The entailment between two dynamic propositions is defined as in (28).

$$(27) \quad \phi(w)(\langle \top, \perp \rangle) \text{ is dynamically true iff } \phi(w)(\langle \top, \perp \rangle) \neq \emptyset$$

$$(28) \quad \phi \text{ entails } \psi \text{ w.r.t } \langle \top, \perp \rangle \text{ iff } \forall w \forall \langle \top', \perp' \rangle \in \phi(w)(\langle \perp, \top \rangle) \rightarrow \exists \langle \top'', \perp'' \rangle \in \psi(w)(\langle \perp', \top' \rangle)$$

Applying **max** to the set (25) yields the maximally informative proposition relative a possible word and an input info-state. For example, given the actual world

w_0 and an input info-state $\langle \top, \perp \rangle$, if Ann and Bob both were late in w_0 , then $\llbracket \text{ANN AND BOB were late} \rrbracket_d$ is maximally informative relative to w_0 and $\langle \top, \perp \rangle$. This dynamic proposition is just the exhaustive answer to the question.

4.3 Short answers = stacks storing the drefs introduced by *wh*-expressions

According to the proposed dynamic semantics of *wh*-questions, each dynamic proposition in the set denoted by a *wh*-question is associated with a dref introduced by the *wh*-expression in the question. These drefs generated by the *wh*-expression are still accessible when the meaning of the whole question is composed. This is essentially different from the static H/K semantics, in which a *wh*-question denotes a set of static propositions, i.e., sets of worlds., which do not track the alternatives generated by a *wh*-expression. As a consequence, it's possible to retrieve the drefs introduced by a *wh*-expression from a dynamicized Hamblin set. These drefs are precisely the possible short answers to the *wh*-question.

Building on the maximal informativity operator **max**, I define an operator **SA**, as in (29), to derive short answers⁸. Informally, **SA** represents such a process: given a question Q , for any world w and info-state $\langle \top, \perp \rangle$, we get a maximally informative answer ϕ to Q (in other words, we have different maximally informative answer relatives to different worlds and info-states); for each ϕ , we retrieve the drefs introduced by *wh*-expressions and finally collect the drefs retrieved from all ϕ -s.

$$(29) \quad \mathbf{SA}(Q) := \lambda i \lambda w \lambda \langle \top, \perp \rangle. \left\{ \langle \top', \perp' \rangle \in \phi(w)(\langle \top, \perp \rangle) \mid \begin{array}{l} \phi = \mathbf{max}_{w, \langle \top, \perp \rangle}(Q) \wedge \\ \perp' - \perp = i \end{array} \right\}$$

Formally, **SA** takes a set of dynamic propositions Q denoted by a question and returns a function from stacks to dynamic propositions (i is the variable for stacks). With respect to a possible world w and an input info-state $\langle \top, \perp \rangle$, a stack that satisfies (29) equals to the subtraction of \perp from the output top stack \perp' , which is generated by updating $\langle \top, \perp \rangle$ with the maximally informative proposition ϕ in the set Q relative to w and $\langle \top, \perp \rangle$. ϕ from Q updates $\langle \top, \perp \rangle$ by adding a dref introduced by the *wh*-expression in the question to \perp and the other drefs to \top . As a result, \perp' differs from \perp in that the former contains one more dref. So, $\perp' - \perp$ results in a stack that only stores the dref introduced by the *wh*-expression.

Let's take the *wh*-question *who was late* as an example. Figure 3 illustrates how the stacks storing drefs introduced by *who* are retrieved. Suppose that only Ann was

⁸ My proposal shares the same intermediate step with Chierchia & Caponigro's (2013). They derive an abstract denotation for a *wh*-question via shifting the question denotation to an exhaustive propositional answer with a Dayal-style answerhood operator. However, their proposal is formalized under the assumption that propositions are sets of possible worlds and doesn't always give rise to correct abstracts.

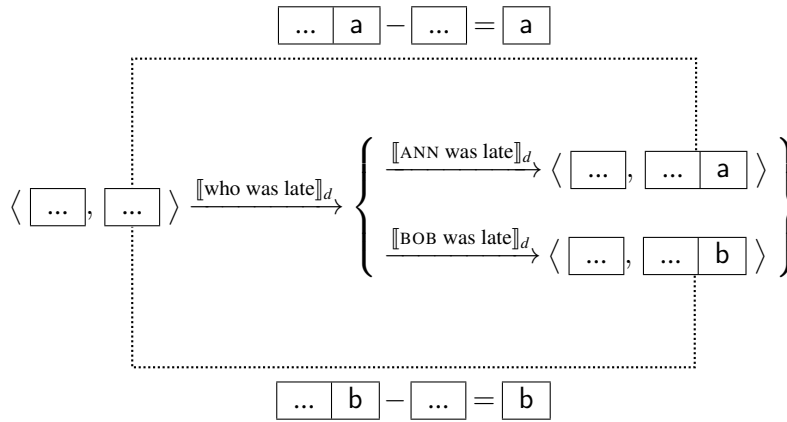


Figure 3: Retrieving drefs introduced by *wh*-expressions

late in w_1 and only Bob was late in w_2 , then the maximally informative proposition relative to w_1 is $[[\text{ANN was late}]_d$ and the one relative to w_2 is $[[\text{BOB was late}]_d$. Subtracting the input bottom stack from each output bottom stack results in two short pieces of these outputs, i.e., \boxed{a} and \boxed{b} . These resulting stacks only store drefs introduced by the *wh*-expression and these drefs are the maximal individual who was late in a possible world.

Accordingly, the retrieved stacks store individuals which resolve the question *who was late* in a possible world. Hence, short answers are formally considered stacks that are taken by (29) and yield a dynamically true proposition relative to an info-state and a possible world, as exemplified by the following paraphrase.

- (30) **SA**($[[\text{who was late}]_d$)(\boxed{a})(w_1)($\langle \top, \perp \rangle$) can be read as: \boxed{a} is the short answer to the question *who was late* relative to w_1 and $\langle \top, \perp \rangle$.

Note that the **max** operator is encoded in **SA**. As a consequence, the short answer derived by **SA** must be exhaustive.

4.4 *Wh*-conditionals: Quantifying over short answers

Following the LKH approach to conditionals, the antecedent of a conditional provides a domain restriction for a quantifier, which may be a (covert) modal or a (covert) quantificational adverb, while the consequent serves as the scope of the quantifier. These quantifiers quantify over possible worlds/situations as well as other variables when they are available. As Chierchia (1992) suggests, they should be interpreted as polyadic quantifiers. The covert adverb **ALWAYS** is assigned the dynamic meaning

in (31) (see also Chierchia 1992).

$$(31) \quad \text{ALWAYS}_{\vec{x},s}. [f(\vec{x})(s)] (f'(\vec{x})(s)) := \\ \lambda_w \lambda \langle \top, \perp \rangle. \left\{ \langle \top, \perp \rangle \left| \begin{array}{l} \forall \vec{x}, s, \langle \top', \perp' \rangle. \langle \top', \perp' \rangle \in f(\vec{x})(s)(\langle \top, \perp \rangle) \wedge s \leq w \\ \rightarrow \exists \langle \top'', \perp'' \rangle \in f(\vec{x})(s)(\langle \top', \perp' \rangle) \end{array} \right. \right\}$$

As discussed in Section 2, I assume that a situation is part of a possible world. **ALWAYS** can bind any other variables in the restriction and scope. The functions f and f' both take a situation argument as well as an argument sequence of any length, including 0, and return a context update.

In a *wh*-conditional, like (32), the restriction and scope of **ALWAYS** are functions yielded by the application of **SA**. The final representation is (33), which says: for each stack i and situation s , if i is the short answer to *who is late* in s , then i is the short answer to *who'll be penalized* in s . This result is what I suggest in Section 2.

$$(32) \quad \text{Shéi chídào, shéi jiù shòufá.} \\ \text{who late who then be.penalized} \\ \text{'Whoever is late, s/he will be penalized.'}$$

$$(33) \quad \text{ALWAYS}_{i,s} [\mathbf{SA}(\llbracket \text{who is late} \rrbracket_d)(i)(s)] (\mathbf{SA}(\llbracket \text{who'll be penalized} \rrbracket_d)(i)(s))$$

5 Applications

5.1 Deriving short answers to *wh*-coordinations

Since the proposed semantics of *wh*-questions is a dynamicized version of the H/K semantics, the denotations of various *wh*-questions have a uniform type. As a result, *wh*-coordination is not problematic. Take the *wh*-conditional in (34) as an example.

$$(34) \quad \text{Nǐ [chī shá^x cài], [hē shá^y jiǔ], wǒ jiù yào [chī shá^x cài], [hē} \\ \text{you eat what dish drink what wine I then must eat what dish drink} \\ \text{shá^y jiǔ].} \\ \text{what wine} \\ \text{'No matter what dish you eat and what wine you drink, I must eat the same} \\ \text{dish and drink the same wine.'}$$

For the *wh*-coordination in the antecedent, each of the *wh*-clauses denote a set of dynamic propositions, as in (35) and (36).

$$(35) \quad \llbracket \text{you eat wh.dish} \rrbracket_d := \{ \llbracket \text{you eat SALAD} \rrbracket_d, \llbracket \text{you eat BEANS} \rrbracket_d \}$$

$$(36) \quad \llbracket \text{you drink wh.wine} \rrbracket_d := \{ \llbracket \text{you drink R.WINE} \rrbracket_d, \llbracket \text{you drink W.WINE} \rrbracket_d \}$$

Deriving short answers from dynamicized Hamblin sets

We can conjoin the sets of dynamic propositions by a pointwise dynamic conjunction, as in (37). Specifically, conjoining two sets of dynamic propositions is reduced to the dynamic conjunction, defined in (38), of the alternatives in the sets.

$$(37) \quad Q_1 \underline{\wedge} Q_2 := \{\phi \triangle \psi \mid \phi \in Q_1, \psi \in Q_2\}$$

$$(38) \quad \phi \triangle \psi := \lambda w \lambda \langle \top, \perp \rangle. \bigcup \left\{ \psi(w)(\langle \top', \perp' \rangle) \mid \langle \top', \perp' \rangle \in \phi(w)(\langle \top, \perp \rangle) \right\}$$

As a result, the meaning of the *wh*-coordination is calculated as (39), a set of conjunctions of dynamic propositions. Since *salad*, *beans*, *red wine* and *white wine* are all introduced by the *wh*-expressions, they are added to the bottom stack.

$$(39) \quad \llbracket \text{you eat wh.dish} \rrbracket_d \underline{\wedge} \llbracket \text{you drink wh.wine} \rrbracket_d = \\ \left\{ \begin{array}{l} \llbracket \text{you eat S} \rrbracket_d \triangle \llbracket \text{you drink R.W.} \rrbracket_d, \llbracket \text{you eat S} \rrbracket_d \triangle \llbracket \text{you drink W.W.} \rrbracket_d, \\ \llbracket \text{you eat B} \rrbracket_d \triangle \llbracket \text{you drink R.W.} \rrbracket_d, \llbracket \text{you eat B} \rrbracket_d \triangle \llbracket \text{you drink W.W.} \rrbracket_d \end{array} \right\}$$

The meaning of the first member in (39) is (40). The output is a set of stack pairs, each of which has a dish and a wine in \perp . Other members in (39) generate the same kind of denotations.

$$(40) \quad \lambda w \lambda \langle \top, \perp \rangle. \{ \langle \top, \perp \cdot s \cdot r \rangle \mid \text{eat}_w(s)(hr) \wedge \text{drink}_w(r)(hr) \}$$

Applying **SA** to the set in (39) leads to the possible short answers to the *wh*-coordination. Given the world w_1 and the info-state $\langle \top, \perp \rangle$, **SA** first picks out from the set in (39) the maximally informative proposition ϕ , which updates $\langle \top, \perp \rangle$ and yields $\langle \top', \perp' \rangle$. \perp' is the extension of \perp , since the former contains the drefs introduced by the *wh*-expressions. Then, **SA** retrieves stacks that are part of \perp' but not \perp . Suppose (40) is the maximally informative proposition in w_1 and $\langle \top, \perp \rangle$, then **SA** retrieves the stack $\boxed{s \mid r}$, which is the short answer to the *wh*-coordination in w_1 . Collecting the stacks retrieved relative to different worlds and info-states together gives us all possible short answers.

The possible short answers to the *wh*-coordination in the consequent are derived in the same way. The modal *yào* quantifies over the short answers and ?? says: for all the accessible worlds w and stacks i , if i is the short answer to the question *what dish does the addressee eat and what wine does the addressee drink* in w , then i is also the short answer to the question *what dish does the speaker eat and what wine does the speaker drink* in w .

5.2 ‘Short’ answers to polar questions

The present analysis won’t over-generate in the case of polar questions. In the present analysis, short answers to questions are actually drefs. Murray (2014)

proposes that a polar question introduces two propositions (sets of possible worlds) as drefs (cf. Krifka 2013). Following her study, I assume that the non-bias polar question in (41) denotes a set containing two dynamic propositions $\llbracket \text{Libai leaves} \rrbracket_d$ and $\llbracket \text{Libai doesn't leave} \rrbracket_d$. The former introduces as a dref the set of worlds in which Libai leaves, whereas the latter the set of worlds in which he doesn't leave.

- (41) Lǐbái zǒu-bù-zǒu?
 Libai leave-not-leave
 'Does Libai leave?'

Let's turn to (42). The polar question in the antecedent introduces propositional drefs: $\{w \mid \text{Libai leaves in } w\}$ and $\{w \mid \text{Libai doesn't leave in } w\}$. By contrast, the polar question in the consequent introduces the other two propositional drefs: $\{w \mid \text{Dufu leaves in } w\}$ and $\{w \mid \text{Dufu doesn't leave in } w\}$

- (42) *Lǐbái zǒu-bù-zǒu, Dùfǔ jìu zǒu-bù-zǒu.
 Libai leave-not-leave Dufu then leave-not-leave

Even though **SA** can retrieve these drefs, no dref introduced by the first question is equivalent to a dref introduced by the second one. As a result, there won't be a stack that is the answer to the first question and also answers the second question. The following formula is never satisfied.

- (43) $\text{ALWAYS}_{i,s} [\text{SA}(\llbracket \text{L l-not-l} \rrbracket)(i)(s)] (\text{SA}(\llbracket \text{D l-not-l} \rrbracket)(i)(s))$

6 Conclusion

Using dynamic semantics, this paper offers a new way to derive short answers to *wh*-questions. It is proposed that a *wh*-question denotes a set of dynamic propositions, each of which is associated with a dref introduced by the *wh*-expression in the question. Retrieving the alternative drefs introduced by a *wh*-expression gives us a set of possible short answers. This paper has also demonstrated that this novel way of deriving short answers provides a more adequate analysis for Mandarin *wh*-conditionals.

The present study shows that short answers can be derived from dynamicized Hamblin sets. It fixes a longstanding issue for the H/K approach—its inability to derive short answers. A host of phenomena that semantically requires short answers are now open for analyses in the H/K approach, including fragment responses to *wh*-questions (Jacobson 2016; Weir 2018), the correlation of *wh*-questions and free relatives (Xiang 2016), quantificational variability effects of questions with collective predicates (Berman 1991; Xiang 2016; Cremers 2018) and the meaning of *namely* phrases (AnderBois & Jacobson 2018).

<i>items</i>	<i>denotations</i>	<i>types</i>
late	$\lambda x \lambda w \lambda \langle \top, \perp \rangle. \{ \langle \top, \perp \rangle \}$ if $\text{late}_w(x)$ else \emptyset	$e \rightarrow D$
who _{w₀}	$\{ \lambda P \lambda w \lambda \langle \top, \perp \rangle. P(x)(w)(\langle \top \cdot x, \perp \rangle) \mid x \in \text{human}_{w_0} \}$	SQ

Table 1: Fragment

A Appendix: The composition of *wh*-questions in dynamic semantics

Our basic types are individuals (type e), truth values ($t ::= \{0, 1\}$), possible worlds (type ω) and stacks (type σ). For convenience, I define the type synonyms: $D ::= \omega \rightarrow (\sigma \times \sigma) \rightarrow (\sigma \times \sigma) \rightarrow t$ for dynamic propositions (i.e., a dynamic proposition is an intensional context change potential), $Sa ::= a \rightarrow t$ for sets of a -type elements, and $Q ::= (e \rightarrow D) \rightarrow D$ for dynamic generalized quantifiers (GQ).

Following Charlow (2014, 2019), the crucial compositional device includes two polymorphic shifters, as in (44), which actually generalize Karttunen’s (1977) compositional theory. Specifically, η can shift any element to a singleton set containing it, as in (44-a), while a *wh*-expression is decomposed into an alternative set m and a scope-taking operator \gg , as in (44-b).

$$(44) \quad \begin{array}{ll} \text{a. } \eta := \lambda x. \{x\} & \eta :: a \rightarrow Sa \\ \text{b. } m^{\gg} := \lambda P. \bigcup_{x \in m} P(x) & \gg :: Sa \rightarrow (a \rightarrow Sb) \rightarrow Sb \end{array}$$

According to Table 1, the *wh*-expression denotes a set of dynamic GQs. The set takes scope via the application of \gg , as in (45). The scope argument is a function from a dynamic GQ to a set of dynamic propositions (type $Q \rightarrow SD$).

$$(45) \quad \mathbf{who}_{w_0}^{\gg} := \lambda \mathcal{P}. \bigcup_{\beta \in \mathbf{who}_{w_0}} \mathcal{P}(\beta) \quad \mathbf{who}_{w_0}^{\gg} :: (Q \rightarrow SD) \rightarrow SD$$

I give a basic derivation for the dynamic denotation of *who*’s *late* in (46). *Who* is shifted to a scope-taker by \gg . It takes scope and leaves a trace β that is itself typed as a dynamic GQ. Hence, the GQ trace also takes scope. \mathbf{Who}^{\gg} is a higher order quantifier. η is applied to the scope of the *wh*-expression and coerces a dynamic proposition into a boring singleton set of the dynamic proposition. The compositional rule that we need is just functional application. The result is a set of dynamic propositions.

$$(46) \quad \mathbf{who}_{w_0}^{\gg} \lambda \beta. \eta (\beta (\lambda x. \text{late}(x))) := \\ \{ \lambda w \lambda \langle \top, \perp \rangle. \{ \langle \top \cdot x, \perp \rangle \mid \text{late}_w(x) \} \mid x \in \text{human}_{w_0} \}$$

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