Wh-questions and their two-layered answerhood

Linmin Zhang, zhanglinmin@gmail.com, the version of January 18, 2024

Abstract

This paper proposes a new perspective on the semantics of *wh*-questions and their answerhood. There are **two layers** involved in answering a *wh*-question: (i) **its maximally informative analytical answer** (which is analytical and world-independent) plus (ii) **additional information** (which can be various kinds of world-dependent information).

This proposal is in the same spirit as Karttunen (1977)'s view that a question denotes its true answers and Dayal (1996)'s view that a *wh*-question presupposes the existence of a maximally informative true answer. I show that a good *wh*-question always has a maximally informative analytical answer, which is true and complete and can be considered equal to the question meaning and constitutes the first layer of the answerhood. Built on this first layer, a typical, acceptable short answer contributes a second layer that provides additional information. Thus, a question like *who smiled* yields an analytically complete true answer: 'the one(s) who smiled'. A short answer like '*My Melody and Kuromi*' contributes further information about this definite item: 'the one(s) who smiled' is identical to (or includes) the sum **My-Melody⊕Kuromi**.

Inspired by the works of Brasoveanu (2013), Charlow (2014, 2017), Bumford (2017) on phenomena that demonstrate split (or multi-layered) semantics (e.g., cumulative-reading sentences, Haddock descriptions), I consider the 'two-layered answerhood' similar to post-suppositional phenomena and implement the proposed perspective within dynamic semantics. I show that the two layers involved in answering a *wh*-question correspond to (i) non-local, relativized definiteness and (ii) cardinality in a cumulative-reading sentence. I analyze various question-related phenomena with the proposed perspective and discuss theoretical implications, especially with regard to (i) L-analyticity (see Gajewski 2002/2016, Abrusán 2014) as the driving force behind question interpretation and (ii) the distinction between an answer-based vs. an issue-based perspective on *wh*-clauses.

Keywords: *Wh*-questions, Answers, Short answers, Dynamic semantics, Definiteness, Uniqueness, Maximality, Informativeness, Post-suppositions, Split semantics, Modified numerals, Cumulative reading, *Wh*-items, Degree questions, QUD, Issues, L-analyticity, Embedded questions, Mention-some questions, Multi-*wh*-questions

1 Introduction

This paper proposes a new perspective on the semantics of *wh*-questions and their answerhood. There are **two layers** involved in answering a *wh*-question: (i) **its maximally informative analytical answer** (which is analytical and world-independent) plus (ii) **additional information** (which can be various kinds of world-dependent information).

The main idea is motivated by the following observation. For a *wh*-question like (1), intuitively, the short answer (2a) is a complete true answer, and its corresponding propositional answer (2b) is actually tautological. However, despite their being true and complete, answers in (2) sound funny and ridiculous to interlocutors: they are derivable from the question itself and only contain known information. Evidently, a good answer should have additional information, which these answers in (2) lack.

In contrast, (3) illustrate what a typical good short answer and its corresponding propositional answer look like. These answers are acceptable precisely because *My Melody and Kuromi* provides additional information about the ones who smiled.

(1) Who smiled?

(2) a. The one(s) who smiled. **Short answer**
b. The one(s) who smiled smiled. **Propositional answer**

(3) a. My Melody and Kuromi. **Typical good, congruent short answer**
b. My Melody and Kuromi smiled. **Propositional answer**

The above observation suggests the desideratum of a good, acceptable (short) answer: **some additional information** is added on top of **something definite** that has already been established and restricted by the *wh*-question itself. In other words, the meaning of a *wh*-question contains the same information as and is thus already equal to a definite item – its maximally informative analytical answer, and what a good short answer further contributes is about and affiliated to this analytical core.

This 'two-layered answerhood' perspective, though obvious and intuitive, has never been investigated in the formal semantics literature on *wh*-questions. In this paper, I aim to show how this perspective sheds new light on various question-related language phenomena and brings theoretical implications. In particular, the discussion in this paper suggests that L(ogical) analyticity (see Gajewski 2002/2016, Abrusán 2014) is likely to be the driving force behind question interpretation, and in this sense, question meaning

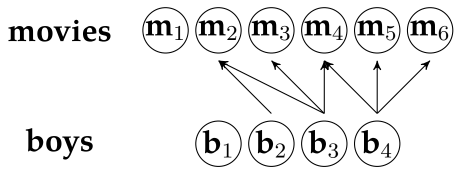

Figure 1: The genuine **cumulative** reading of (4) is **true** in this context.

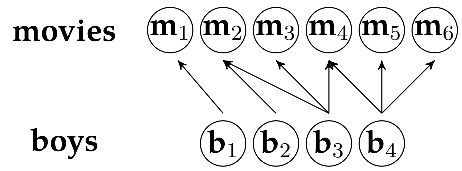

Figure 2: The genuine **cumulative** reading of (4) is **false** in this context.

proper is constant across possible worlds (i.e., analytical) and thus should be characterized in an extensional way.

The rest of the paper starts with a discussion of cumulative-reading sentences, another linguistic phenomenon demonstrating multi-layered semantics that involves definiteness and additional information (Section 2). Based on this parallelism between cumulative-reading sentences and '*wh*-question + acceptable short answer', I present the main proposal within dynamic semantics (Section 3) and show how this proposal immediately brings welcome consequences (Section 4). Section 5 analyzes various empirical phenomena hotly discussed in the recent literature on question semantics. Section 6 makes a comparison with related works and addresses theoretical implications, especially with regard to (i) L-analyticity and (ii) the distinction between an answer-based vs. an issue-based perspective on *wh*-questions. Section 7 concludes.

2 Inspiration from cumulative-reading sentences

Here I show the conceptual parallelism between **cumulative-reading sentences** and '*wh*-question + short answer', highlighting their shared mechanism: multi-layered semantics that involves **(i) non-local definiteness and (ii) additional information**.

Cumulative-reading sentences like (4) contain multiple **modified numerals** (see the underlined parts in (4)) and demonstrate **multi-layered semantics**.

(4) $\underline{\text{Exactly 3 boys}}$ saw $\underline{\text{exactly 5 movies}}$. $\rightsquigarrow$ **Cumulative reading**

The **cumulative reading** of (4) means that some boys saw some movies, and the cardinality of all boys that saw some movies is equal to 3, and the cardinality of all movies seen by some boys is equal to 5.[1] Intuitively, this reading is true under the scenario in Fig.

[1]In addition to this cumulative reading, sentence (4) also has a distributive reading, which is not discussed in this paper (see Brasoveanu 2013 and Charlow 2017 for more details).

1, but false under the scenario in Fig. 2 (see Krifka 1999, Brasoveanu 2013, Charlow 2017).

For this cumulative reading, the contrast between our judgements under the scenarios in Fig. 1 and Fig. 2 rules out a scope-taking analysis like (5). In (5), one modified numeral (here *exactly 3 boys*) scopes over another (here *exactly 5 movies*), yielding a so-called pseudo-cumulative reading that is true under the scenario in Fig. 2.[2]

(5) The **pseudo-cumulative reading** of (4): The maximal boy-sum [such that they saw a total of 5 movies between them] has the cardinality of 3.
(*exactly 3 boys* takes scope over *exactly 5 movies*)
$\rightsquigarrow$ true under Fig. 2 (There are two such witnesses: $b_1 \oplus b_2 \oplus b_4$ and $b_2 \oplus b_3 \oplus b_4$. There is no larger boy-sum satisfying the restriction that 'they saw in total five movies between them'.)

Thus, as pointed out by Krifka (1999), Brasoveanu (2013), Charlow (2017), the derivation of the genuine cumulative reading of (4) involves no scope taking between the two modified numerals. In Krifka (1999)'s words, 'they ask for an interpretation strategy in which all the NPs in a sentence are somehow **interpreted in parallel**.'

Brasoveanu (2013) develops a **post-suppositional** account for this genuine cumulative reading of (4) within dynamic semantics. As sketched out in (6), modified numerals make semantic contribution in multiple layers:

(6) $\exists^{|x|=3}[\textsc{boy}(\mathrm{x})](\exists^{|y|=5}[\textsc{movie}(y)](\textsc{saw}(x,y)))$ **Genuine cumulative reading** of (4)
$\Leftrightarrow \underbrace{\sigma x \sigma y[\textsc{boy}(x) \wedge \textsc{movie}(y) \wedge \textsc{saw}(x,y)]}_{\text{mereologically maximal } x \text{ and } y} \wedge \underbrace{|y| = 5 \wedge |x| = 3}_{\text{cardinality tests}}$ (Brasoveanu 2013: (68))

First, **existential quantification**, or the **non-deterministic introduction of discourse referents** (dref): each modified numeral introduces a potentially plural dref (here x and y). Relevant restrictions are added onto these drefs: $\textsc{boy}(x)$, $\textsc{movie}(y)$, and $\textsc{saw}(x,y)$ (cumulative closure is assumed for lexical relations when needed). This step yields the meaning that there are movie-seeing boy-sums and movie-sums seen by boys.

Second, **non-local maximization**: at the sentential level, after all the drefs are introduced and relevant restrictions are added, modified numerals contribute mereology-based maximality operators. In (6), the two maximality operators σ are applied simultaneously, selecting out the maximal plural individuals, i.e., the maximal movie-seeing boy-sum, and the maximal movie-sum seen by boys.

[2] I will address the availability of this pseudo-cumulative reading in (5) later in Section 3.4.

Finally, **checking cardinalities**: as the last step, cardinality tests brought by modified numerals are applied onto the maximal drefs, checking whether the cardinality of the relativized maximal boy-sum (i.e., those who saw movies) is equal to 3, and whether the cardinality of the relativized maximal movie-sum (i.e., those seen by boys) is equal to 5.

The 'parallel interpretation strategy' advocated by Krifka (1999) crucially consists in (i) splitting the semantics of modified numerals into several layers and (ii) delaying the application of all cardinality tests until the sentential level, after maximization.

Otherwise, as illustrated in (7), if the maximality operator and cardinality test associated with *exactly 5 movies* are embedded within the scope of the maximization of boy-sums, the derivation leads to the pseudo-cumulative reading in (5).

(7) $$\underbrace{\sigma x[\textsc{boy}(x) \wedge \underbrace{|\sigma y[\textsc{movie}(y) \wedge \textsc{saw}(x,y)]| = 5}_{\text{mereologically maximal } y \text{ and its cardinality}}]}_{\text{mereologically maximal } x} \wedge \underbrace{|x| = 3}_{\text{cardinality of the maximal } x}$$

$\rightsquigarrow$ the pseudo-cumulative reading paraphrased in (5)

Brasoveanu (2013)'s account for the genuine cumulative reading is **post-suppositional** in that the semantics of cardinality is considered situated at another dimension, serving as delayed tests on the output context, i.e., after the at-issue meaning (which involves dref introduction and restriction as well as maximization) is evaluated.

Charlow (2017) discusses two other approaches, i.e., (i) higher-order dynamic generalized quantifiers plus sub-typing, and (ii) update semantics (see e.g., Veltman 1996), and both share the same spirit as Brasoveanu (2013): Cardinality tests need to be delayed until they are applied to the sentence-level, relativized maximal / definite drefs.

With regard to both (i) non-local, sentence-level, relativized definiteness and (ii) delayed tests (applied to the sentence-level, relativized definite drefs), '*wh*-question + short answer' is exactly parallel to the phenomenon of cumulative-reading sentences.

2.1 Non-local, sentence-level, relativized definiteness

Given that cardinality is entirely separated aside (to another dimension) and comes into play at a delayed stage, the maximality operators amount to taking effect simultaneously at the sentence / global level, resulting in relativized definiteness:

(8) $\sigma x[\textsc{boy}(x) \wedge \sigma y[\textsc{movie}(y) \wedge \textsc{saw}(x,y)]] \wedge |y| = 5 \wedge |x| = 3$ (Brasoveanu 2013: (68c))

$\Leftrightarrow \sigma x \sigma y[\textsc{boy}(x) \wedge \textsc{movie}(y) \wedge \textsc{saw}(x,y)] \wedge |y| = 5 \wedge |x| = 3$ (Brasoveanu 2013: (68d/e))

Thus, the meaning of the cumulative-reading sentence (4) is not about the cardinality of all boys or all movies (which are 4 and 6 in Fig. 1), but the cardinality of all boys who saw movies and all movies seen by boys (which are 3 and 5 in Fig. 1). In other words, definiteness is not at the local DP level of modified numerals or in an absolute sense, but relativized at the level where maximization actually takes place, i.e., at the sentence level (right before cardinality comes into play).

A *wh*-question naturally demonstrates the same kind of relativized definiteness. For *wh*-question (1) (see (9), I assume that *who* lexically carries a restriction so that its domain is humans), the definiteness associated with *who* is not in an absolute sense, but rather in a relativized sense, i.e., at the sentence-level. Eventually, *who* / *which humans* in (9) is not about all humans in context, but rather about all humans who smiled (see (9a) vs. (9b)).

(9) <u>Who</u> smiled? (= <u>which humans</u> smiled?) (= (1))

a. $[\![(1)]\!] \rightsquigarrow \sigma x[\textsc{human}(x) \wedge \textsc{smiled}(x)]$ the human(s) who smiled

b. $[\![(1)]\!] \not\rightsquigarrow \sigma x[\textsc{human}(x)] \wedge \textsc{smiled}(x)$ the humans smiled

Thus for both *wh*-question (1)/(9) and cumulative-reading sentence (4), definiteness is relativized by information beyond the immediate DP.

2.2 Delayed tests that bring additional information

For cumulative-reading sentences, delayed cardinality tests are applied to the non-local, sentence-level, relativized definite drefs, contributing additional information. A corresponding sentence without additional information sounds degraded (see (10b)).

(10) a. Exactly 3 boys saw exactly 5 movies. (= (4))

$\sigma x \sigma y[\textsc{boy}(x) \wedge \textsc{movie}(y) \wedge \textsc{saw}(x, y)] \wedge |y| = 5 \wedge |x| = 3$ (= (6))

b. ??The boys saw the movies. Cumulative reading in the scenario of Fig. 1

$\sigma x \sigma y[\textsc{boy}(x) \wedge \textsc{movie}(y) \wedge \textsc{saw}(x, y)]$

(The semantics of definite determiner *the* is split into (i) dref introduction and (ii) non-local, sentence-level maximization (see Bumford 2017))

Intended meaning: 'the boys who saw movies saw the movies seen by boys.'

Similarly, as already mentioned in Section 1, without additional information, an answer like *the ones who smiled* (see (2a)) sounds funny and ridiculous in answering the question *who smiled* (see (1)/(9)).

Degraded or funny cases like (10b) and (2) are reminiscent of similar phenomena that demonstrate **meaning triviality** at the sentence level.

For example, as illustrated in (11), meaning derivation resulting in the maximal girl-sum is fine for a DP (see (11a)), but unacceptable for sentence (11b). This phenomenon has been discussed for a long time: The use of definite determiner *the* is ungrammatical in a *there*-existential sentence (see e.g., Barwise and Cooper 1981; cf. (17)). (11b) is parallel to (10b) in that meaning derivation of these degraded **sentences** (cf. DP in (11a)) ends with the application of maximality operators, and no additional meaning is added onto the definite drefs at the sentence level.

On the other hand, as illustrated in (11c), when *the* is replaced by *exactly 4*, a modified numeral that contributes not only dref introduction and non-local maximization (see (12); see also Szabolcsi 1997, Krifka 1999, de Swart 1999, Umbach 2005), but also additional cardinality information, the sentence becomes acceptable.

(11) a. The girls ✓ as a DP: $\sigma x[\textsc{girl}(x)]$

b. *There are the girls. ✗ as a sentence: $\sigma x[\textsc{girl}(x)]$

c. There are exactly 4 girls. $\underbrace{\sigma x[\textsc{girl}(x)]}_{\text{dref introduction and maximization}} \wedge \underbrace{|x| = 4}_{\text{additional cardinality information}}$

(12) **Maximality effect of modified numerals**: an additive continuation is infelicitous

a. Mary fed <u>two puppies</u>. They are cute. Perhaps she fed <u>more</u>.

b. Mary fed <u>at least two puppies</u>. They are cute. #Perhaps she fed <u>more</u>.

Another phenomenon is related to Haddock descriptions (see Haddock 1987, Bumford 2017). Under a context where there are multiple salient rabbits and hats (see Fig. 3), (13a) is a felicitous DP to denote R2, i.e., the unique rabbit contained in the unique rabbit-containing hat, H1. Here the uniqueness of the rabbit R2 and the hat H1 is also defined in a relativized sense, involving information beyond the local DPs. However, as a sentence, (13b) sounds degraded. Similar to (10b) and (11b), meaning derivation of sentence (13b) also ends with the application of definiteness operators, and no additional meaning is added onto the sentence-level relativized definite drefs.

On the other hand, (13c) is supposed to convey the same information as (13b), but when uniqueness is considered additional cardinality information affiliated to sentential-level maximization, we intuitively feel that sentence (13c) is acceptable.

(13) a. the rabbit in the hat ✓ as a DP: $\iota x \iota y[\textsc{rabbit}(x) \wedge \textsc{hat}(y) \wedge \textsc{in}(x, y)]$

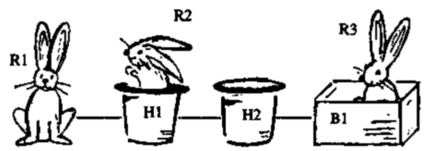

Figure 3: ⟦the rabbit in the hat⟧ denotes R2.

b. *The rabbit is in the hat. ✗ as a sentence: $\iota x \iota y[\textsc{rabbit}(x) \wedge \textsc{hat}(y) \wedge \textsc{in}(x,y)]$
Intended: 'the rabbit that is in a hat is in the hat that contains it.'

c. Exactly 1 rabbit is in exactly 1 hat.
$\underbrace{\sigma x \sigma y[\textsc{rabbit}(x) \wedge \textsc{hat}(y) \wedge \textsc{in}(x,y)]}_{\text{dref introduction and maximization}} \wedge \underbrace{|y| = 1 \wedge |x| = 1}_{\text{additional cardinality information}}$

These data raise two issues. First, (non-local, relativized) definiteness (e.g., $\sigma x[P(x)]$, $\iota x[P(x)]$, $\sigma x \sigma y[P(x) \wedge Q(y) \wedge R(x,y)]$, $\iota x \iota y[P(x) \wedge Q(y) \wedge R(x,y)]$) is acceptable as the meaning of a DP (see (11a) and (13a)), but corresponding sentences with the same meaning derivation are ungrammatical (e.g., (10b)/(11b)/(13b)). Second, though (10b)/(11b)/(13b) sound degraded, their paraphrases (see (14a), (14b)) or similar sentences that convey this kind of sentential-level definiteness (see (14c)) sound better and grammatically acceptable, despite also being tautological and funny.

(14) a. The boys who saw movies saw the movies seen by them.
$\rightsquigarrow \sigma x \sigma y[\textsc{boy}(x) \wedge \textsc{movie}(y) \wedge \textsc{saw}(x,y)]$ (cf. (10b))

b. The rabbit that is in a hat is in the hat that contains it.
$\rightsquigarrow \iota x \iota y[\textsc{rabbit}(x) \wedge \textsc{hat}(y) \wedge \textsc{in}(x,y)]$ (cf. (13b))

c. The ones who smiled smiled. (in answering *who smiled*)
$\rightsquigarrow \sigma x[\textsc{human}(x) \wedge \textsc{smiled}(x)]$ (= (2b))

It is not the goal of the current work to provide a full account for these issues. In this section, I simply aim to show the parallelism between '*wh*-question + good short answer' and data like cumulative-reading sentences: They all require additional information affiliated to sentence-level, relativized definite items. Based on this parallelism, I will propose to consider a non-analytical short answer to a *wh*-question (e.g., (3a)) a kind of post-supposition, similar to cardinality information for cumulative-reading sentences.

That being said, I include a brief discussion on these issues here, and there will be related discussion in Sections 4.2 and 6.1. The contrast between these ungrammatical sentences (10b)/(11b)/(13b) and grammatical sentences in (14) reflects the notion of **L(ogical)-Analyticity** (or L-triviality, see e.g., Gajewski 2002/2016, Abrusán 2014).

Not all sentences with trivial meaning (i.e., tautological or contradictory) are ungrammatical (e.g., (15) is grammatical), but those that are L-analytically trivial are ungrammatical. According to Gajewski (2002/2016), a sentence is L-analytically trivial if the replacement of every occurrence of a non-logical word (i.e., a lexical word) by another one leads to a trivial logical skeleton. Thus a sentence like (15) is not L-trivial.

(15) Every actor is an actor. Tautological **but not L-analytically tautological**
The logical skeleton is not tautological: Every P is Q. $\forall x[P(x) \to Q(x)]$

Abrusán (2014) provides a further explanation behind Gajewski (2002/2016)'s theory: The meaning of lexical words is usually vague and context-dependent. For a sentence like (15), there can be a reinterpretation for each occurrence of *actor*, making the actual interpretation of (15) non-tautological.

Ungrammatical sentences (10b)/(11b)/(13b) and grammatical sentences in (14) differ greatly with regard to how many occurrences of lexical words they contain, leading to distinct logical skeletons. As illustrated in (16), the logical skeleton of (10b)/(13b) is L-trivial, while that of (14a)/(14b) is not. Similarly, (17) is supposed to have the same meaning as (11b). However, by containing *exist*, which is intuitively a lexical word, (17) has a non-L-trivial logical skeleton and is judged acceptable. Thus Gajewski (2002/2016)'s theory explains our different intuitions for (10b)/(11b)/(13b) vs. (14)/(17). Definite DP conveying the meaning $\sigma x[P(x)]$ (see (11a) and (13a)) can also encounter other lexical words in sentence development, avoiding L-triviality eventually.

(16) **Logical skeletons**:

a. (10b)/(13b): The P R the Q. **L-trivial**
$\rightsquigarrow \forall x \forall y[P(x) \wedge Q(y) \wedge R(x,y) \to R(x,y)]$

b. (14a)/(14b): The P_1 that R_1 Q_1 R_0 the Q_2 that P_2 R_2. **Not L-trivial**
$\rightsquigarrow \forall x \forall y \forall x' \forall y'[P_1(x) \wedge Q_1(y) \wedge R_1(x,y) \wedge P_2(x') \wedge Q_2(y') \wedge R_2(x',y') \to R_0(x,y')]$

(17) The girls exist. (cf. ungrammatical sentence (11b): *there are the girls)
The P Q. $\rightsquigarrow \forall x[P(x) \to Q(x)]$ **Not L-trivial**

Another way to consider this is that meaning derivation for (relativized) definiteness (e.g., $\sigma x[P(x)]$, $\sigma x \sigma y[P(x) \wedge Q(y) \wedge R(x,y)]$) involves dref introduction and maximization. However, if no further information is provided for the (mereologically) maximal dref(s), the step of maximization is superfluous: i.e., '$\sigma x[P(x)]$' does not contribute more information than '$\exists x[P(x)]$' (which involves dref introduction alone) and thus should be ruled out by the latter. Among various non-deterministic items, the existence of a (mereologically) maximal one is usually guaranteed (see also Section 4.2). Picking out this definite item is meaningful for a conversation only if interlocutors intend to talk more about it. Thus after deriving definiteness, human cognition cannot stop at this L-trivial result and should have the intuitive tendency to provide additional information. In this sense, L-analyticity is likely to be the driving force that makes an expression interpreted as a question, asking for additional information, i.e., asking to be answered.

2.3 Interim summary

To sum up, '*wh*-question + good short answer' and cumulative-reading sentences are parallel phenomena. As summarized in (18), they all include three parts: (i) dref introduction, (ii) sentence-level relativized definiteness, and (iii) additional information.[3]

For a cumulative-reading sentence, all these three parts are contained within one sentence and contributed by modified numerals, while for '*wh*-question + short answer', the first two parts and the third part are separated, contributed by *wh*-item(s) and a good short answer respectively. A *wh*-question itself is actually similar to L-trivial / L-analytical sentences like **there are the girls*. Presumably, that's why it is interpreted as a question and calls for additional information (e.g., from a good short answer; see also Section 6.1).

(18) **'*Wh*-question + good short answer' vs. a cumulative-reading sentence**

Shared elements	**Cumulative-reading sentence**	**'*wh*-question + short answer'**
dref introduction	modified numeral(s)	*wh*-item(s)
relativized definiteness		
additional information		a good short answer

The striking parallelism between '*wh*-question + short answer' and a cumulative-reading sentence is not a coincidence. After presenting the main proposal in Section 3, I will further explain this parallelism in Section 3.4.

[3] The dref introduction of *wh*-questions will be further addressed in Sections 3.1 and 4.1.

3 Proposal: *Wh*-questions and answers

This section provides a formal semantic analysis of *wh*-questions and their two-layered answerhood within dynamic semantics. In Section 3.1, I follow Brasoveanu (2013)'s analysis of cumulative-reading sentences and use Dynamic Predicate Logic (DPL, Groenendijk and Stokhof 1991) to analyze basic cases like *who smiled* (see (1)) and their answerhood.[4] Section 3.2 proposes a generalization, with the replacement of mereology-based maximization by informativeness-based maximization. Based on this, Section 3.3 addresses degree questions. Section 3.4 compares the maximality operators involved in the interpretation of *wh*-questions and cumulative-reading sentences.

3.1 Basic cases of *wh*-questions

Based on the parallelism between '*wh*-question + good short answer' and a cumulative-reading sentence, I propose to derive their meaning in the same way within dynamic semantics. Here meaning derivation is a series of updates from an information state to another, and an information state is a set of assignment functions (of type $\langle st\rangle$, see (19)). Given the distributivity of DPL (see (19b) and Groenendijk and Stokhof 1990b), an update can be considered a relation between assignment functions (i.e., it takes an assignment function as input and returns a set of assignment functions).

(19) DPL (see Groenendijk and Stokhof 1990b, 1991):

a. **Information state** i: a set of assignment functions g — Type: $\langle st\rangle$

b. **Update** r: from an information state to another — Type: $\langle st, st\rangle$
Given that for every information state i, $r(i) = \bigcup_{g\in i} r(\{g\})$, an update can be considered a relation between assignment functions (of type $\langle s, st\rangle$).

c. **Truth**: an update is true if it does not end with an empty set.

The semantic derivation of the cumulative-reading of (4) is illustrated in (20). In (20a), modified numerals first work like existential quantifiers and introduce drefs, and these drefs get restrictions like $\textsc{movie}(y), \textsc{boy}(x), \textsc{saw}(x, y)$. In (20b), mereology-based maximality operators $\mathbf{M}_u$ and $\mathbf{M}_\nu$ pick out the maximal boy-sum and movie-sum that

[4] With regard to cumulative-reading sentences and Haddock descriptions, Charlow (2014, 2017), Bumford (2017) use monads to develop a more compositional formal implementation. This issue of compositionality is not essential to the main goal of the paper, so for presentation simplicity, I follow Brasoveanu (2013)'s formalism within DPL, with slight notation differences.

satisfy all the relevant restrictions. Finally, in (20c), $\mathbf{3}_u$ and $\mathbf{5}_\nu$ check the cardinalities of these relativized maximal boy-sum and movie-sum. Eventually, the cumulative reading of (4) is an update such that it is true if the cardinality of all boys who saw movies is 3 and the cardinality of all movies seen by boys is 5.

(20) $[\![\text{Exactly three}^u \text{ boys saw exactly five}^\nu \text{ movies}]\!]$ (=(4))

$$\Leftrightarrow \underbrace{\mathbf{3}_u[\mathbf{5}_\nu}_{\text{cardinality tests}} \; [\underbrace{\mathbf{M}_u[\mathbf{M}_\nu}_{\text{maximality}} \underbrace{[\![\text{some}^u \text{ boys saw some}^\nu \text{ movies}]\!]}_{\text{dref introduction}}]]]]$$

a. **Introducing drefs**: $[\![\text{some}^u \text{ boys saw some}^\nu \text{ movies}]\!]$

$$\Leftrightarrow \lambda g.\left\{ g^{\nu\mapsto y}_{u\mapsto x} \;\middle|\; \textsc{movie}(y), \textsc{boy}(x), \textsc{saw}(x,y) \right\}$$

b. **Simultaneously applying mereology-based maximality operators**:

$$\mathbf{M}_u \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\{h \in m(g) \mid \neg\exists h' \in m(g).h(u) \sqsubset h'(u)\}$$

$$\mathbf{M}_\nu \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\{h \in m(g) \mid \neg\exists h' \in m(g).h(\nu) \sqsubset h'(\nu)\}$$

Thus $\mathbf{M}_u[\mathbf{M}_\nu[\![\text{some}^u \text{ boys saw some}^\nu \text{ movies}]\!]]$

$$\Leftrightarrow \mathbf{M}_u[\mathbf{M}_\nu[\lambda g.\left\{ g^{\nu\mapsto y}_{u\mapsto x} \;\middle|\; \textsc{movie}(y), \textsc{boy}(x), \textsc{saw}(x,y) \right\}]]$$

$$\Leftrightarrow \lambda g.\left\{ g^{\nu\mapsto y}_{u\mapsto x} \;\middle|\; \begin{array}{l} y = \Sigma y[\textsc{movie}(y) \wedge \textsc{saw}(x,y)] \\ x = \Sigma x[\textsc{boy}(x) \wedge \textsc{saw}(x,y)] \end{array} \right\}$$

c. **Checking cardinalities**:

$$\mathbf{3}_u \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } |g(u)| = 3 \\ \varnothing & \text{otherwise} \end{cases}, \quad \mathbf{5}_\nu \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } |g(\nu)| = 5 \\ \varnothing & \text{otherwise} \end{cases}$$

Thus $\mathbf{3}_u[\mathbf{5}_\nu[\mathbf{M}_u[\mathbf{M}_\nu[\![\text{some}^u \text{ boys saw some}^\nu \text{ movies}]\!]]]]$

$$\Leftrightarrow \lambda g.\left\{ g^{\nu\mapsto y}_{u\mapsto x} \;\middle|\; \begin{array}{l} y = \Sigma y[\textsc{movie}(y) \wedge \textsc{saw}(x,y)] \\ x = \Sigma x[\textsc{boy}(x) \wedge \textsc{saw}(x,y)] \end{array} \right\}, \text{if } |x| = 3 \wedge |y| = 5$$

Similarly, (21) illustrates the meaning derivation of a *wh*-question. Just like modified numerals, which make semantic contributions in several layers, *wh*-items also include an indefinite component (see (21a)) and a definite component (see (21c)).[5] Thus, in (21a), who^u first non-deterministically introduces a dref in a domain of humans, i.e., satisfying $\textsc{human}(x)$. In (21b), more restrictions (here $\textsc{smiled}(x)$) are added onto relevant drefs. Finally, as the last step in deriving a *wh*-question, in (21c), a mereology-based maximality operator $\mathbf{M}_u$ (see (22)) is applied, picking out the maximal sum of smiling humans.

[5] See Russell (1905), Bumford (2017) for a similar perspective on definite determiner *the*: its indefinite component introduces a dref, and its definite component checks uniqueness (see also (10) and (13)). See more discussions on the connection between *wh*-questions and definite descriptions in Section 4.

(21) Who^u smiled? ***wh*-question** (= (1))

$$\Leftrightarrow \underbrace{\mathbf{M}_u}_{\text{maximality / answerhood}} \quad \underbrace{[\![\text{some}^u \text{ (humans) smiled}]\!]}_{\text{dref introduction}}$$

a. **Introducing a dref with a *wh*-item:**

$$\underbrace{[\![\text{who}^u]\!]}_{\text{the indefinite component of } who} = [\![\text{some}^u \text{ (humans)}]\!] = \lambda g.\ \{g^{u\mapsto x} |\ \textsc{human}(x)\}$$

b. **More restrictions are added:**

$[\![\text{who}^u \text{ smiled}]\!] = [\![\text{some}^u \text{ (humans) smiled}]\!]$

$= \lambda g.\ \{g^{u\mapsto x} |\ \textsc{human}(x), \textsc{smiled}(x)\}$

c. **Applying a mereology-based maximality / answerhood operator:**

$$\underbrace{\mathbf{M}_u}_{\text{the definite component of } who} \quad [\![\text{some}^u \text{ (humans) smiled}]\!]$$

$$\Leftrightarrow \mathbf{M}_u[\lambda g.\ \left\{ g^{u\mapsto x} \middle| \textsc{human}(x), \textsc{smiled}(x) \right\}]$$

$$\Leftrightarrow \lambda g.\ \left\{ g^{u\mapsto x} \middle| x = \Sigma x[\textsc{human}(x) \wedge \textsc{smiled}(x)] \right\}$$

Obviously, the maximality operator involved in (21c) can actually be considered an answerhood operator. The application of this operator results in the analytically complete true answer to a *wh*-question (see more discussions on maximality later).

(22) **Maximality / answerhood operator**: (**mereology-based**)

$\mathbf{M}_u/\mathbf{Ans}_u \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\{h \in m(g) \mid \neg\exists h' \in m(g).h(u) \sqsubset h'(u)\}$

Next, (23) illustrates the meaning of a good short answer to a *wh*-question like (21). As defined in (23), $[\textbf{My-Melody} \oplus \textbf{Kuromi}]_u$ is considered a post-suppositional test, playing the same role as cardinality tests do in a cumulative-reading sentence (see (20c)). If $[\textbf{My-Melody} \oplus \textbf{Kuromi}]_u$ is a complete answer, this test checks whether the maximal dref in (21c) is identical to the sum $[\textbf{My-Melody} \oplus \textbf{Kuromi}]_u$. If $[\textbf{My-Melody} \oplus \textbf{Kuromi}]_u$ is a potentially partial answer, this test checks whether the sum $[\textbf{My-Melody} \oplus \textbf{Kuromi}]_u$ is part of the maximal dref in (21c).[6]

(23) **Good short answer as a post-suppositional test**: (see (3a))

a. **As a complete answer:**

$[\textbf{My-Melody} \oplus \textbf{Kuromi}]_u \overset{\text{def}}{=}$

[6] We should actually first check whether $\textbf{My-Melody} \oplus \textbf{Kuromi} \in \textbf{Domain}(g(u))$, which I omit here.

$$\lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } g(u) = \textbf{My-Melody} \oplus \textbf{Kuromi} \\ \varnothing & \text{otherwise} \end{cases}$$

b. **As a potentially partial answer:**

$$[\textbf{My-Melody} \oplus \textbf{Kuromi}]_u \overset{\text{def}}{=}$$

$$\lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } g(u) \sqsupseteq \textbf{My-Melody} \oplus \textbf{Kuromi} \\ \varnothing & \text{otherwise} \end{cases}$$

Applying the meaning of the short answer in (23) to the meaning of the *wh*-question in (21) results in a corresponding propositional answer.

(24) **Deriving a propositional answer from a short answer**:

$[\![$[My-Melody and Kuromi]$_u$ smiled$]\!]$ (= (3b))

$$\underbrace{[\textbf{My-Melody} \oplus \textbf{Kuromi}]_u}_{\text{short answer (see (23))}}\underbrace{[\mathbf{M}_u[\lambda g.\left\{g^{u\mapsto x}\;\middle|\; \textsc{human}(x), \textsc{smiled}(x)\right\}]]}_{\textit{wh}\text{-question (see (21))}}$$

$$\Leftrightarrow \lambda g.\left\{g^{u\mapsto x}\;\middle|\; x = \Sigma x[\textsc{human}(x) \wedge \textsc{smiled}(x)]\right\},$$

if x = **My-Melody** $\oplus$ **Kuromi** (or $x \sqsupseteq$ **My-Melody** $\oplus$ **Kuromi**)

3.2 Informativeness-based maximality / answerhood operator

For a *wh*-question like *who smiled* (see (1)/(21)), the domain of the *wh*-item, *who*, is a set of (potentially plural) individuals, and the predicate, *smile*, is inherently distributive. Thus the application of the mereology-based maximality operator (see (22)) results in the maximally informative analytical answer, *the one(s) who smiled* (see (2a)):

(25) $\forall x \forall y[x \sqsubseteq y \rightarrow \textsc{smiled}(y) \vDash \textsc{smiled}(x)]$

(Since x is a part of y, $\textsc{smiled}(y)$ entails and is more informative than $\textsc{smiled}(x)$)

More generally, I propose an **informativeness-based maximality / answerhood operator**, as shown in (26). After drefs are non-deterministically introduced and relevant restrictions are added, the application of this operator picks out the definite dref that eventually leads to the maximally informative analytical answer to the *wh*-question.

(26) **Maximality / answerhood operator**: (**informativeness-based**)

$\mathbf{M}_u/\mathbf{Ans}_u \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\{h \in m(g) \mid \neg\exists h' \in m(g).G(h(u)) <_{\text{info}} G(h'(u))\}$

(G is a context-dependent measurement function of informativeness.)

Obviously, the mereology-based maximality operator in (22) is consistent with and a special case of this informativeness-based maximality operator (see (25)). Below I show how this more generalized maximality / answerhood operator yields maximally informative analytical answers for degree questions, i.e., questions that involve domains different from sets of individuals.

3.3 Degree questions and weak island effects

For degree questions like (27), the domain of the *wh*-item is a scale, i.e., a totally ordered set of scalar values, here a set of height degrees (see e.g., von Stechow 1984, Kennedy 1999, Schwarzchild and Wilkinson 2002, Schwarzschild 2008, Beck 2011, Zhang and Ling 2021). In (27a), the indefinite component of the *wh*-item, *how*, non-deterministically introduces a degree dref (that is a height). In (27b), relevant restrictions are added, i.e., $\text{HEIGHT}(\text{Junhyuk}) \geq d$ (the height of Junhyuk reaches d). Then based on the informativeness-based maximality / answerhood operator $\mathbf{M}_u$ defined in (26), in (27c), the maximally informative degree d that satisfies restrictions is picked out (i.e., the height measurement of Junhyuk). Thus the height degree of Junhyuk is the maximally informative analytical answer to this degree question (see also Section 4.6).

(27) How^u tall is Junhyuk? **Degree question**

$$\Leftrightarrow \underbrace{\mathbf{M}_u}_{\text{maximality / answerhood}} \underbrace{[\![\text{Junhyuk is some}^u \text{ tall}]\!]}_{\text{dref introduction}}$$

a. **Introducing a degree dref:**

$$\underbrace{[\![\text{how}^u]\!]}_{\text{the indefinite component of } how} = [\![\text{some}^u \text{ (height)}]\!] = \lambda g.\ \{g^{u\mapsto d} \mid \text{HEIGHT}(d)\}$$

b. **More restrictions are added:**

$[\![\text{Junhyuk is how}^u \text{ tall}]\!] = [\![\text{Junhyuk is some}^u \text{ tall}]\!]$

$= \lambda g.\ \{g^{u\mapsto d} \mid \text{HEIGHT}(\text{Junhyuk}) \geq d\}$

($[\![\text{tall}]\!]_{d,et} \overset{\text{def}}{=} \lambda d.\lambda x.\text{HEIGHT}(x) \geq d$, i.e., $[\![\text{tall}]\!]$ relates an individual and a degree; see e.g., von Stechow 1984, Schwarzschild 2008, Beck 2011)

c. **Applying an informativeness-based maximality / answerhood operator:**

$$\underbrace{\mathbf{M}_u}_{\text{the definite component of } how} [\![\text{Junhyuk is some}^u \text{ tall}]\!]$$

$$\Leftrightarrow \mathbf{M}_u[\lambda g.\ \left\{g^{u\mapsto d} \middle| \text{HEIGHT}(\text{Junhyuk}) \geq d\right\}]$$

$$\Leftrightarrow \lambda g.\left\{g^{u\mapsto d}\,\middle|\, d = \textsc{height}(\text{Junhyuk})]\right\}$$

($\forall d_1 \forall d_2[d_1 > d_2 \rightarrow \textsc{height}(\text{Junhyuk}) \geq d_1 \vDash \textsc{height}(\text{Junhyuk}) \geq d_2]$, i.e., the increase of informativeness correlates with the increase of height degrees.)

(28a) illustrates the meaning of a good short answer to the degree question (27). $[\textbf{6-feet}]_u$ works like a post-suppositional test, providing additional information about the maximally informative analytical answer in (27c). Applying this post-suppositional test to the meaning of the *wh*-question yields a corresponding propositional answer (see (28b)). (28a)/(28b) result in an update such that it is true if the height of Junhyuk reaches 6 feet.

(28) a. 6 feet. **Short answer** to (27)

$$[\textbf{6-feet}]_u \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } g(u) \geq 6' \\ \varnothing & \text{otherwise} \end{cases}$$

b. $[\![$Junhyuk is $[6 \text{ feet}]_u$ tall$]\!]$ **Propositional answer** to (27)

$$\underbrace{[\textbf{6-feet}]_u}_{\text{short answer (see (28a))}} \quad \underbrace{[\mathbf{M}_u[\lambda g.\left\{g^{u\mapsto d}\,\middle|\, \textsc{height}(\text{Junhyuk}) \geq d]\right\}]}_{\text{degree question (see (27))}}$$

$$\Leftrightarrow \lambda g.\left\{g^{u\mapsto d}\,\middle|\, d = \textsc{height}(\text{Junhyuk})]\right\}, \text{ if } d \geq 6'$$

The current analysis can naturally account for a difference between domains of individuals vs. degrees. As illustrated in (29), with a domain of individuals, a *wh*-question involving negation is grammatical (see (29a)), but with a domain of degrees, a degree question involving negation is ungrammatical (see (29b)). The degradedness of (29b) is called **weak island effects**, and negation is considered a creator of weak island effects, preventing the displacement of *how* (but not *who*) in forming a *wh*-quesion (see e.g., Szabolcsi and Zwarts 1993, Szabolcsi 2006, Abrusán 2014).

Under the current analysis, the semantic derivation of *wh*-questions is based on the application of an informativeness-based maximality operator (see (26)), i.e., the existence of a maximally informative analytical answer. A domain of height degrees is totally ordered and has no maximal member. As a consequence, (29b) has no maximally informative analytical answer, leading to weak island effects.

(29) a. Who^u didn't come? **With a domain of individuals**

$$\rightsquigarrow \mathbf{M}_u[\lambda g.\left\{g^{u\mapsto x}\,\middle|\, \textsc{human}(x), \neg\textsc{came}(x)\right\}]$$

Its most informative analytical answer exists: $\Sigma x[\textsc{human}(x) \wedge \neg\textsc{came}(x)]$

b. *How^u tall isn't Junhyuk? **With a domain of degrees**

$\rightsquigarrow \mathbf{M}_u[\lambda g.\left\{g^{u\mapsto d} \middle| \neg\textsc{height}(\text{Junhyuk}) \geq d\right\}]$

Its most informative analytical answer does not exist: there is no maximal degree d satisfying $\neg\textsc{height}(\text{Junhyuk}) \geq d$, i.e., $\textsc{height}(\text{Junhyuk}) < d$

3.4 More on the role of sentence-level maximality

Section 2 addresses the parallelism between '*wh*-question + short answer' and a cumulative-reading sentence. In fact, this striking parallelism is not a coincidence.

Composing a *wh*-question with its short answer amounts to a propositional answer (see (24); see also Section 4.4). The cumulative-reading sentence (4)/(30b) can be considered a propositional answer to a multi-*how-many* question like (30a), providing cardinality information about the definite items: the boys who saw movies, and the movies seen by boys. In this sense, the parallel interpretation of modified numerals for (4)/(30b) and the seeming lack of pseudo-cumulative reading (see (5)) are actually based on a salient underlying question under discussion (QUD, see Roberts 1996/2012) like (30a).

Krifka (1999) also considers cumulative-reading sentences similar to focus phenomena (cf. Brasoveanu 2013), involving picking out the most informative utterance from its alternative set. Thus Krifka (1999)'s view also assumes a QUD like (30a).[7]

(30) a. <u>How many^u boys</u> saw <u>how many$^\nu$</u> movies? QUD for the cumulative reading

b. Exactly 3_u boys saw exactly 5_ν movies. (= (4))

$$\mathbf{3}_u[\mathbf{5}_\nu[\underbrace{\mathbf{M}_u[\mathbf{M}_\nu}_{\text{to address a multi-how-many question}}[\lambda g.\left\{g^{u\mapsto x}_{\nu\mapsto y} \middle| \textsc{movie}(y), \textsc{boy}(x), \textsc{saw}(x,y)\right\}]]]]$$

With a different underlying QUD like (31a), i.e., a single *how-many* question, a pseudo-cumulative reading that involves scope-taking between modified numerals becomes available (see (31b)).[8]

[7] See also Krifka (1999), Zhang (2023a)'s discussion on cumulative-reading sentences like *In Guatemala, (at most) 3% of the population own (at least) 70% of the land* and how an underlying QUD determines the measurement of maximal informativeness and our intuition in interpreting a cumulative-reading sentence.

[8] Buccola and Spector (2016) (among others) addresses the semantics of sentences with multiple modified numerals like (i), confirming the existence of such an asymmetric, pseudo-cumulative reading.

(i) Less than 5 guests drank over 20 bottles of beers between them. (Buccola and Spector 2016: (2a))

(31) a. How many^u boys saw exactly 4 movies (between them)? (with Fig. 2)

b. Exactly 3_u boys saw exactly 4 movies (between them). $\rightsquigarrow b_1 \oplus b_2 \oplus b_3$

Pseudo-cumulative reading is available: the unique maximal boy-sum [such that they saw a total of 4 movies between them] has the cardinality of 3.

$$\mathbf{3}_u[\underbrace{\mathbf{M}_u}_{\text{to address a single } \textit{how-many} \text{ question}} [\lambda g\,.\left\{g^{u\mapsto x} \,\middle|\, \textsc{boy}(x), |\Sigma y[\textsc{movie}(y) \wedge \textsc{saw}(x,y)]| = 4\right\}]]$$

These examples (30) and (31) demonstrate the connection between (i) a *wh*-question that serves as an underlying QUD (see (30a) and (31a)) and (ii) sentence-level, relativized maximization (used in the derivation of propositional answers to QUDs, see (30b) and (31b)). The genuine cumulative reading of (30b) is based on the simultaneous application of two sentence-level maximality operators, corresponding to the two parallel instances of *how-many* in (30a), while the pseudo-cumulative reading in (31b) has only one sentence-level maximality operator, corresponding to the one instance of *how-many* in (31a) (see related discussion in Section 5.3).

Thus a cumulative-reading sentence is itself a propositional answer to its QUD, representing a special case of the more general phenomenon '*wh*-question + short answer'. Maximality operators involved in the derivation of the cumulative reading are indeed answerhood operators and need to be applied simultaneously at the sentence level, before the application of cardinality tests which bring additional information.

The split, multi-layered semantics, i.e., sentence-level definiteness plus separate additional information, is particularly observable for a cumulative-reading sentence, due to the presence of multiple modified numerals that require parallel interpretation. But

Existing literature (see e.g., Gentile and Schwarz 2018) also discusses single *how-many* questions with a non-distributive (i.e., collective or cumulative) predicate like (31a) and their uniqueness presupposition.

For example, (31a) presupposes the unique existence of a boy-sum such that these boys saw exactly 4 movies between them. Obviously, a propositional answer to such a question like (31a) must be a pseudo-cumulative-reading sentence like (31b).

In (31), I use *exactly 4 movies* instead of *exactly 5 movies*, because under Fig. 2, a question like *how many boys saw exactly 5 movies (between them)?* violates this uniqueness presupposition – there are two witnesses: $b_1 \oplus b_2 \oplus b_4$ and $b_2 \oplus b_3 \oplus b_4$ (See (5); see also Gentile and Schwarz 2020, Xiang 2021a, Buccola 2022.)

Presumably, this uniqueness presupposition for (31a) is related to the *wh*-item *how many*, which counts the cardinality of the unique boy-sum assigned to u. When cardinality is not involved, a *wh*-question like (iia) does not involve uniqueness, i.e., there can be potentially more than one boy groups such that for each boy group, group members saw exactly 5 movies between them (see (iib); see also Zhang 2018). A detailed investigation of these phenomena is beyond the current research (see e.g., Buccola 2022).

(ii) a. Which^u boy group(s) saw exactly 5^ν movies (between them)? (with Fig. 2)

b. The group $b_1 \oplus b_2 \oplus b_4$ and the group $b_2 \oplus b_3 \oplus b_4$.

after all, such a multi-layered perspective should systematically underlie the analysis of the more generalized phenomenon '*wh*-question + short answer'.

4 Consequences

The above proposal shows (i) a compositional derivation of the meaning of a *wh*-question, i.e., the derivation of its maximally informative analytical answer, and (ii) how a good short answer contributes additional information about the maximally informative analytical answer. In this section, I show how this proposal naturally inherits many existing insights on *wh*-questions and brings welcome consequences.

4.1 Comorovski (1996): *Wh*-items support cross-sentential anaphora

Under the current proposal, *wh*-items are parallel to modified numerals (see (4)) and definite determiner *the* (see (10b) and (13); see Russell 1905, Bumford 2017) in including (i) an indefinite component and (ii) a definite component. This view naturally explains the behavior of *wh*-items in introducing drefs and supporting cross-sentential anaphora (see e.g., Comorovski 1996, Li 2021), as illustrated in (32):

(32) **Comorovski (1996)'s examples on anaphora to *wh*-expressions**

a. Which^u boy took the pictures and with which of his$_u$ cameras? (p.24, (40))

b. Who^u did you talk to and when did you talk to them$_u$? (p.25, (42))

c. What^u did Mary say and why did she say it$_u$? (p.25, (43))

Comorovski (1996) points out that 'it is ultimately an indefinite that introduces the relevant discourse referent in (32) (p.25)'. However, *wh*-item are different from indefinites, but similar to modified numerals and definite descriptions, in further containing a definite component (i.e., a maximality operator, see (26)).

This is evidenced by the contrast between (33) and (34). In (33), since u is not necessarily assigned to the maximal laughing-boy-sum, a continuation that involves more laughing boys beyond $g(u)$ is allowed. On the other hand, for the sentences in (34), u is either assigned to the absolute maximal boy-sum (see (34a), where a maximality operator is applied at the DP level for *the*^{u} *boys*) or the relativized maximal boy-sum that laughed (see (34b) and (34c), where a maximality operator is applied at the sentence level), a continuation that involves more laughing boys beyond $g(u)$ is intuitively disallowed.

(33) **Indefinites**: Additivity is allowed:

$\underbrace{\underline{\text{A}^u\text{ boy}}\text{ laughed.}}_{\lambda g.\{g^{u\mapsto x}|\ \textsc{boy}(x)\wedge\textsc{laughed}(x)\}}$ $\underbrace{\text{He}_u\text{ is noisy.}}_{\textsc{noisy}(g(u))}$ Perhaps $\underline{\text{other boys}}$ laughed too.

(34) **Definite descriptions, modified numerals, *wh*-items**: Additivity is disallowed:

a. $\underbrace{\underline{\text{The}^u\text{ boys}}\text{ laughed.}}_{\lambda g.\{g^{u\mapsto x}|\ x=\Sigma x[\textsc{b}(x)]\},\textsc{laughed}(g(u))}$ $\underbrace{\text{They}_u\text{ are noisy.}}_{\textsc{noisy}(g(u))}$ #Maybe $\underline{\text{other boys}}$ laughed too.

b. $\underbrace{\underline{\text{Exactly 3}^u\text{ boys}}\text{ laughed.}}_{\lambda g.\{g^{u\mapsto x}|\ x=\Sigma x[\textsc{b}(x)\wedge\textsc{l}(x)]\},|g(u)|=3}$ $\underbrace{\text{They}_u\text{ are noisy.}}_{\textsc{noisy}(g(u))}$ #Maybe $\underline{\text{other boys}}$ laughed too.

c. $\underbrace{\underline{\text{Which}^u\text{ boys}}\text{ laughed?}}_{\lambda g.\{g^{u\mapsto x}|\ x=\Sigma x[\textsc{b}(x)\wedge\textsc{laughed}(x)]\}}$ $\underbrace{\text{They}_u\text{ are noisy.}}_{\textsc{noisy}(g(u))}$ #Maybe $\underline{\text{other boys}}$ laughed too.

4.2 Karttunen (1977) and Dayal (1996): (maximally informative) true answers

The current proposal inherits the spirit of Karttunen (1977): A *wh*-question has the same meaning as its **true** propositional answers (cf. Hamblin (1973)'s '**possible** answer' view, which will be discussed in Sections 5.7 and 6.2). The current proposal makes an even stronger claim: A *wh*-question has the same meaning as its **complete true answers**.

(35)
$$\underbrace{[\![\text{who}^u\text{ came}]\!]}_{\textit{wh}\text{-question}} = \underbrace{[\![\text{the}^u\text{ ones who came (came)}]\!]}_{\text{complete true short / propositional answer (most informative analytical answer)}} =$$
$$\lambda g.\, \{g^{u\mapsto x} |\ x = \Sigma x[\textsc{human}(x) \wedge \textsc{came}(x)]\}$$

The difference between the current proposal and Karttunen (1977) amounts to whether a maximality operator $\mathbf{M}_u$ / $\mathbf{Ans}_u$ is applied (see (21c) and (26)). As illustrated in (35), both a *wh*-question and its most informative analytical answer (i.e., the complete true answer) are analyzed as the same update, by assigning u to the definite dref that leads to maximal informativeness. The application of this maximality operator picks out a definite dref, deriving the most informative analytical answer and guaranteeing the meaning equivalence between a *wh*-question and this most informative analytical answer.

For Karttunen (1977), a *wh*-question is like an existential sentence: e.g., *who came* means *someone came*. Karttunen (1977)'s view seems to reflect the idea that the application of $\mathbf{M}_u$ / $\mathbf{Ans}_u$ is L-trivial and superfluous (see Section 2.2), but it cannot explain humans' different reactions and interpretations towards *who came* vs. *someone came* as matrix and embedded clauses (see Section 6.1).

Moreover, data involving cross-sentential anaphora and whether a continuation of additivity is allowed (see (33) vs. (34) in Section 4.1) provide empirical evidence for the current view: a maximality operator should be involved in the meaning of a *wh*-question.

Weak island data also provide empirical evidence for maximization. Under Karttunen (1977)'s view, *How tall isn't Junhyuk* (see (29b)) is predicted to be interpretable, meaning *The height of Junhyuk doesn't reach some degree*, and *Junhyuk isn't 7 feet tall* can be a true answer here. However, this degree question is unacceptable, contrary to Karttunen (1977)'s prediction.

The current proposal inherits Dayal (1996)'s insight: a question presupposes the existence of a maximally informative true answer. Evidently, whether a *wh*-question meets this presuppositional requirement amounts to whether the maximality operator $\mathbf{M}_u$ / $\mathbf{Ans}_u$ is applicable. As far as the maximality operator is applicable, the most informative analytical answer is derivable, indicating the existence of a maximally informative true answer (which is this most informative analytical answer itself). In Section 3.3, weak island data (see (29)) illustrate degraded cases, which violate Dayal (1996)'s presuppositional requirement (see also Abrusán 2014): the underlying reason can be traced back to the failure in applying the maximality operator $\mathbf{M}_u$ / $\mathbf{Ans}_u$.

A relevant note is that under the current proposal, the meaning of a *wh*-question and its most informative analytical answer is L-analytical (see Sections 2.2 and 6.1), staying invariant and independent from which possible world(s) are under consideration.

In other words, the interpretation of the *wh*-question *who came* and its analytical answer *the one(s) who came* (*came*) is similar to universal quantifier (e.g., *everyone who came*) and definite descriptions (e.g., ***the temperature of water*** *is changing*, *Anna didn't give* ***the only invited talk at the conference***) in having nothing to do with world-dependent existence or measurement. The meaning proper of *who came* and its answer *the one(s) who came* (*came*) does not tell anything about whether, in a certain possible world, there exist people who came, just like the meaning proper of *the ice point of water* does not provide any information about a world-dependent measurement.

This independence from possible worlds is in line with Coppock and Beaver (2015)'s view on definiteness: 'definiteness marks a (weak) uniqueness, [...] Definite descriptions are fundamentally **predicative**, presupposing uniqueness but not existence'. Under the current proposal, the maximality operator (see (26)) plays the same role as the definite component in definite determiner *the*, guaranteeing the uniqueness of the analytical answer that reaches maximal informativeness, but not world-dependent existence.

4.3 Jacobson (2016) on short answers

The current proposal on good short answers is in line with Jacobson (2016)'s insight: For a *wh*-question, its short answer cannot be derived by (i) generating the long / propositional answer first and (ii) deleting some parts from this long answer (see (36b)); rather, short answers like (36c) are directly generated, containing no silent linguistic materials like *My Melody invited . . . to have a pizza*.

(36) a. Q: Who^u did My Melody invite to have a pizza?
b. A: ~~My Melody invited~~ Kuromi$_u$ ~~to have a pizza~~. Jacobson (2016): impossible
c. A: Kuromi$_u$. Jacobson (2016): yes!

(37) $$[\![(36c)]\!] = [\![\text{Kuromi}_u]\!] = \textbf{Kuromi}_u \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } g(u) = (\text{or } \sqsupseteq)\textbf{Kuromi} \\ \varnothing & \text{otherwise} \end{cases}$$

Evidently, under the current proposal, a short answer like (36c) is analyzed as a post-suppositional test, checking whether the dref assigned to u (i.e., $g(u)$) is equal to (or includes) Kuromi (see (37)). No silent materials like *My Melody invited . . . to have a pizza* is involved in the meaning of this short answer in (37).

As a post-suppositional test, (37) brings additional information about the analytical answer by indicating (i) which dref in the *wh*-question the information **Kuromi**$_u$ is connected with and (ii) whether this connection is an identity relation (which yields a complete answer) or a part-whole relation (which yields a potentially partial answer).

There is empirical evidence suggesting that these two kinds of information should indeed be included in the short answer.

First, the dref connection between *who*^{u} in (36a) and Kuromi$_u$ in (36c) can be considered a phenomenon of cross-sentential anaphora (see also Section 4.1). Prominence in how we pronounce the *wh*-question (36a) and the short answer (36c) helps establish this connection: (i) in English, the *wh*-item (here *who*) is moved to the sentence-initial position; (ii) *Kuromi*, which constitutes the post-suppositional test in (37), is the only word pronounced in the short answer (36c).

Actually Jacobson (2016) points out that for a *wh*-question, a short answer is a genuine **answer** that addresses the *wh*-question, while a corresponding propositional answer is a derived **reply**. Under the current analysis, applying this short answer to the question meaning derives the propositional answer (see (24)), i.e., *My Melody invited Kuromi$_F$ to have a pizza*. We intuitively put stress on *Kuromi* in pronouncing this propositional answer, indicating that *Kuromi* (the genuine answer part) bears focus and refers back to and provides additional information about *who^u* (*My Melody invited to have a pizza*).

Then, the distinction between a complete and a potentially partial short answer can also be reflected by prosody. Usually, a complete answer that **fully resolves a QUD** is indicated by the use of a falling intonation, while a potentially partial answer is indicated by the use of a rising contour, suggesting that the QUD might not be fully resolved (see also the discussion on mention-some *wh*-questions in Section 4.5).

4.4 The categorial approach

According to the categorial approach (Hausser and Zaefferer 1978, Hausser 1983; see also Section 6.1 for more discussion), a *wh*-question denotes a function (see (38a)), which, when applied to a short answer, generates a (potentially complete true) propositional answer (see (38b) and (38c)).

(38) **Categorial approach** (Hausser and Zaefferer 1978, Hausser 1983):

a. **Question meaning**: $[\![\text{who smiled}]\!] = \lambda x.\textsc{smiled}(x)$ $\rightsquigarrow$ a function of type $\langle et \rangle$

b. **Short answer 1**: $[\![\text{Cinnamoroll}]\!] = \text{Cinnamoroll}_e$ (of type e)

Propositional answer 1: $[\![[\text{Cinnamoroll}]_F \text{ smiled}]\!]$

$\Leftrightarrow [\lambda x.\textsc{smiled}(x)]\ \text{Cinnamoroll} \Leftrightarrow \textsc{smiled}(\text{Cinnamoroll})$

c. **Short answer 2**: My Melody and Kuromi

(i) $[\![\text{My Melody and Kuromi}]\!] = [\text{My-Melody} \oplus \text{Kuromi}]_e$

Propositional answer 2: $[\![[\text{My Melody and Kuromi}]_F \text{ smiled}]\!]$

$\Leftrightarrow \textsc{dist}[\text{My-Melody} \oplus \text{Kuromi}][\lambda x.\textsc{smiled}(x)]$

$\Leftrightarrow \forall x[x \sqsubseteq_{\text{atom}} \text{My-Melody} \oplus \text{Kuromi} \rightarrow \textsc{smiled}(x)]$

(Since the predicate *smile* is distributive, I assume a silent distributivity operator here: $\textsc{dist} \overset{\text{def}}{=} \lambda X_e.\lambda P_{\langle et \rangle}.\forall x[x \sqsubseteq_{\text{atom}} X \rightarrow P(x)]$)

(ii) $[\![\text{My Melody and Kuromi}]\!] = \lambda P.[\text{My-Melody}(P) \wedge \text{Kuromi}(P)]$ GQ

Propositional answer 2: $[\![[\text{My Melody and Kuromi}]_F \text{ smiled}]\!]$

$\Leftrightarrow [\lambda P.[\text{My-Melody}(P) \wedge \text{Kuromi}(P)]][\lambda x.\textsc{smiled}(x)]$

Obviously, the categorial approach is a concrete implementation of the view later advocated by Jacobson (2016): a short answer is more basic than its corresponding propositional answer, and it is a short answer that constitutes the basis for deriving its corresponding propositional answer, not vice versa (see Section 4.3).

The current proposal inherits this spirit of the categorial approach but also improves on it conceptually, empirically, and technically, overcoming many difficulties that challenge the original categorial approach (see Xiang 2021b for more dicussion).

Conceptual improvement The current proposal provides a better understanding and a more uniform treatment on the connection between a short answer and a *wh*-question.

Under the traditional categorial approach, the meaning of a propositional answer is derived by applying the function that represents the meaning of a *wh*-question to a short answer (see (38)). However, problems immediately arise and call for stipulations.

For example, in (38c), when the *wh*-question (see (38a)) has an inherently distributive predicate (here *smile*), but the short answer refers to a plural individual (i.e., a sum), the function that represents the question meaning (see (38a)) cannot be applied to the sum directly. Either a type shifter like a distributivity operator needs to be assumed, or alternatively, the short answer needs to be considered a generalized quantifier (GQ) of type $\langle et, t\rangle$. Remedies to save composition are available, but a uniform perspective on the connection between a *wh*-question and its answerhood is lost.

Besides, other short answers like *everyone* and *My Melody or Kuromi* (i.e., GQ) are also considered problematic for the traditional categorial approach and require adjustments (see e.g., Jacobson 2016, Xiang 2021a; see Section 5.2).

Under the current approach, the meaning of a *wh*-question is equivalent to its most informative analytical answer, and a genuine short answer is a post-suppositional test applied to this most informative analytical answer and provides additional information. Thus no stipulation is needed, and the short answers in (38b) and (38c) can be treated in exactly the same way: for the maximal dref composed of smiling people, we check whether **Cinnamoroll** (see (38b)) or **My-Melody⊕Kuromi** (see (38c)) is equivalent to (or included in) this maximal dref. Section 5.2 will further show how to deal with complex short answers like GQ. Eventually, they also provide additional information to analytical answers and can be characterized as post-suppositional tests.

Empirical improvement The current proposal accounts for more empirical phenomena. For example, Xiang (2021b) points out that, under the traditional categorial approach, a *wh*-item is considered a λ-operator (see (38a)), thus this analysis fails to capture the widely, cross-linguistically observed parallelism between *wh*-items and indefinites.

Under the current analysis, *wh*-items are analyzed in exactly the same way as modified numerals and definite descriptions in containing an indefinite and a definite component (see Section 4.1), naturally leading to the parallelism between *wh*-items and indefinites (e.g., in introducing drefs and supporting cross-sentential anaphora).

Technical improvement Xiang (2021b) also points out that the traditional categorial approach faces technical deficiencies with regard to (i) composing multi-*wh*-questions and (ii) question coordination. Sections 5.3 and 5.6 will show how the current proposal can be naturally extended to handle these cases.

4.5 The parallelism between *wh*-questions and *wh*-free-relatives

The current analysis also explains the parallelism between *wh*-questions and *wh*-free-relatives (see Caponigro 2003, 2004, Chierchia and Caponigro 2013), because both are equivalent to the most informative analytical answer to a *wh*-question.

As illustrated in (39), (39a), which contains a *wh*-free-relative, and (39b), which contains a definite DP, have the same meaning. This truth-conditional equivalence is explained by the analysis in (40). In (40), $\mathbf{Ans}_u$ works like a mereological maximality operator, leading to the maximal sum of things cooked by Adam (see (22) and (26)).

(39) a. Jie tasted <u>what^u Adam cooked</u>. (Caponigro 2004: p.39, (2a))
b. Jie tasted <u>the^u things Adam cooked</u>.

(40) $[\![$what^u Adam cooked$]\!]$
$= \mathbf{Ans}_u[\lambda g.\ \{g^{u\mapsto x}|\textsc{cook}(\text{Adam}, x)\}]$
$= \lambda g.\ \{g^{u\mapsto x}|\ x = \Sigma x[\textsc{cook}(\text{Adam}, x)]\}$
$= [\![$the^u things Adam cooked$]\!]$

As illustrated in (41) and (42), there is also a parallelism between mention-some *wh*-questions (see (41)) and mentions-some *wh*-free-relatives (see (42)).

(41) Who^u can help her? *Wh*-question

(42) Mary was looking for who^u can help her. *Wh*-free-relative
a. = Mary was looking for <u>someone^u</u> that can help her.
b. ≠ Mary was looking for <u>all the^u people</u> that can help her.

Our natural interpretation for (41) and (42) does not necessarily result in the mereologically maximal dref that includes all the people that can help her, suggesting that these sentences have a mention-some reading. Moreover, mention-some *wh*-questions and *wh*-free-relatives allow for a continuation with additivity (see (43) and (44), cf. (34c)).

(43) a. A: Who^u can help her?
b. B: Me$_u$.↘ <u>Others</u> can help her too. (↘: a falling tone ⇝ QUD is fully resolved)

(44) Mary was looking for who^u can help her. She called me$_u$. <u>Others</u> can help her too.

Under the current proposal, I actually consider $\mathbf{Ans}_u$ an informativeness-based maximality operator, which selects the dref that leads to maximal informativeness (see (26), repeated here in (45)). Thus the application of $\mathbf{M}_u/\mathbf{Ans}_u$ does not always result in a mereologically maximal dref (see also Section 3.3 on degree questions).

(45) **Maximality / answerhood operator** (= (26)): (**informativeness-based**)
$\mathbf{M}_u/\mathbf{Ans}_u \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\{h \in m(g) \mid \neg\exists h' \in m(g).G(h(u)) <_{\text{info}} G(h'(u))\}$
(G is a context-dependent measurement function of informativeness.)
a. For **mention-some *wh*-questions**, $\forall h, h' \in m(g).G(h(u)) = G(h'(u))$

Presumably, for mention-some *wh*-questions and *wh*-free-relatives like (41)/(42), the specific implementation of $\mathbf{Ans}_u$ is such that the informativeness measurement G for assigned drefs results in a constant value (see (45a)). Intuitively, this constant informativeness measurement means that the QUD *Who^u can help her* is fully (not partially) resolved as far as u is mapped to someone that can help her (e.g., assigning u to a dref x_1 is considered as informative as assigning u to a sum $x_1 \oplus x_2$). Every assignment yields an equally maximal informativeness. With such a constant informativeness measurement, the update of a mention-some *wh*-question can be eventually achieved with a choice function, which randomly chooses a dref to assign to u (see (59)). Hence, the dref assigned to u is not necessarily mereologically maximal, and the mention-some reading is derived. I leave a detailed investigation of this idea for future research.

4.6 The parallelism between *wh*-questions and concealed questions

The current analysis also captures the parallelism between *wh*-questions and concealed questions. Syntactically, a concealed question looks like a definite DP, but semantically, it works like a *wh*-question (see, e.g., Nathan 2006, Barker 2016).

In (46) and (47), the content of what Kuromi knows is expressed as a *wh*-question in (46) and as a concealed question in (47). *Wh*-item *how*^{u} and definite determiner *the*^{u} work in the same way. Both include (i) an indefinite component that introduces a dref (here a degree dref) and supports cross-sentential anaphora and (ii) a definite component that leads to definiteness / maximal informativeness (see Sections 3 and 4.1). Thus the meaning equivalence between (46) and (47) is naturally explained.

(46) Kuromi knows $\underbrace{\text{how}^u \text{ tall Junhyuk is}}_{\lambda g\,.\,\{g^{u\mapsto d} \mid\ d=\text{HEIGHT}(\text{Junhyuk})\}}$. My Melody is shorter than that$_u$.

(47) Kuromi knows $\underbrace{\text{the}^u \text{ height of Junhyuk}}_{\lambda g\,.\,\{g^{u\mapsto d} \mid\ d=\text{HEIGHT}(\text{Junhyuk})\}}$. My Melody is shorter than that$_u$.

(Although gradable adjective *tall* and relational noun *height* belong to different syntactic categories, I assume that they have the same lexical meaning, relating a degree and an individual: i.e., $\lambda d.\lambda x.\text{HEIGHT}(x) \geq d$ (see (27b))).

Presumably, for both a degree question like *how tall Junhyuk is* and a concealed question like *the height of Junhyuk*, their question interpretation is rooted in their L-analyticity (see Sections 2.2, 5.6, and 6.1).

5 Further extensions

Now I show how the current proposal can be extended to account for various empirical phenomena, including (i) correlation between analytical answers (Section 5.1), (ii) short answers that are not individuals or entities (Section 5.2), (iii) multi-*wh*-questions (Section 5.3), (iv) strong, weak, and intermediate exhaustivity in interpreting embedded *wh*-questions (Section 5.4), (v) quantificational variability (Section 5.5), (vi) question coordination (Section 5.6), and (vii) question dependency (Section 5.7).

Along the discussion, I will show that many of these *wh*-question-related phenomena are mainly built on the first layer of the answerhood, i.e., the maximally informative analytical answer to a *wh*-question. In other words, their interpretation is invariant and independent from specific possible worlds.

5.1 Correlation between analytical answers (and *wh*-conditionals)

Cross-linguistically, there are constructions that involve two *wh*-questions, addressing the correlation between the maximally informative analytical answers to the two *wh*-questions. Obviously, this kind of correlation itself provides additional information about the two analytical answers, removing L-analyticity at the sentence level.

For example, (48) means that the complete true analytical answer to the question *who*^{u} *comes* correlates with or depends on the complete true analytical answer to the question *who*$^\nu$ *is invited*. As proposed in (49), **depend-on**$_{u,\nu}$ works as a post-suppositional test, checking whether there is a function f mapping the maximal dref assigned to ν (i.e., $g(v)$) to the maximal dref assigned to u (i.e., $g(u)$). In other words, $g(\nu)$ is the independent variable of this function f, and $g(u)$ is the dependent variable.

(48) <u>Who^u comes</u> depends on <u>who$^\nu$ is invited</u>. (see also Karttunen 1977: (7))

a. **Deriving maximally informative analytical answers:**

$$[\![\text{who}^u \text{ comes}]\!] \Leftrightarrow \mathbf{M}_u[\lambda g.\left\{g^{u\mapsto x}\,\middle|\, \textsc{human}(x), \textsc{come}(x)\right\}]$$

$$\Leftrightarrow \lambda g.\left\{g^{u\mapsto x}\,\middle|\, x = \Sigma x[\textsc{human}(x) \wedge \textsc{come}(x)]\right\}$$

$$[\![\text{who}^\nu \text{ is invited}]\!] \Leftrightarrow \mathbf{M}_\nu[\lambda g.\left\{g^{\nu\mapsto y}\,\middle|\, \textsc{human}(y), \textsc{be-invited}(y)\right\}]$$

$$\Leftrightarrow \lambda g.\left\{g^{\nu\mapsto y}\,\middle|\, y = \Sigma y[\textsc{human}(y) \wedge \textsc{be-invited}(y)]\right\}$$

b. **Additional information as a post-suppositional test:** [[(48)]]

$$\Leftrightarrow \lambda g.\left\{g^{\substack{\nu\mapsto y\\ u\mapsto x}}\,\middle|\, \begin{array}{l} y = \Sigma y[\textsc{human}(y) \wedge \textsc{be-invited}(y)] \\ x = \Sigma x[\textsc{human}(x) \wedge \textsc{come}(x)] \end{array}\right\}, \text{ if } \exists f.f(g(\nu)) = g(u)$$

(49) $$[\textbf{depend-on}]_{u,\nu} \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } \exists f.f(g(\nu)) = g(u) \\ \varnothing & \text{otherwise} \end{cases}$$

Wh-conditionals in Mandarin Chinese can be accounted for in exactly the same way.

According to Liu (2017), Xiang (2021b), H. Li (2019, 2021), a *wh*-conditional sentence like (50) includes two questions, here *who*^{u} *loses the bet* and *who*$^\nu$ *pays*, and the short answer to the first *wh*-question (called 'antecedent *wh*-clause') is equivalent to the short answer to the second one (called 'consequent *wh*-clause').

(50) shéi^u shū-le, shéi$^\nu$ (jiù) qǐngkè
who^u lose-ASP who$^\nu$ (then) pay

'For every person x, if x is the one losing the bet, x is the one paying.' (H. Li 2021)

As shown in (51) and (52), this intuitive reading is naturally accounted for. I assume that a silent post-suppositional test **equivalence**$_{u,\nu}$ connects the two *wh*-questions in a *wh*-conditional, checking whether the two maximally informative analytical answers (i.e., the maximal drefs assigned to u and ν) are equivalent.

(51) $[\![(50)]\!] \Leftrightarrow \lambda g.\left\{ g^{\nu\mapsto y}_{u\mapsto x} \;\middle|\; \begin{array}{l} y = \Sigma y[\textsc{human}(y) \wedge \textsc{pay}(y)] \\ x = \Sigma x[\textsc{human}(x) \wedge \textsc{lose}(x)] \end{array} \right\}$, if $g(\nu) = g(u)$

(52) $\textbf{equivalence}_{u,\nu} \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } g(\nu) = g(u) \\ \varnothing & \text{otherwise} \end{cases}$

There are other cases of Chinese wh-conditionals. As pointed out by Xiang (2021b), in (53), 'some true short answer of the consequent *wh*-clause is not a true short answer of the antecedent clause, or equivalently, that the complete true short answer of the antecedent *wh*-clause is only a partial true short answer of the consequent clause. (p.632).'

(53) nǐ xiǎng jiàn shéi^u, wǒ jiù yāoqǐng shéi$^\nu$. dàn wǒ yě hùi yāoqǐng
you want meet who^u I then invite who$^\nu$ but I also will invite
<u>qítā-rén</u>
<u>other-person</u>
'Whomever you want to see, I will invite him. But I will also invite some other people.' (Xiang 2021b: (91))

Under the current analysis, we still only need to consider the maximally informative analytical answers to the two *wh*-questions, i.e., the maximal drefs assigned to u and ν. A silent post-suppositional test provides additional information about $g(u)$ and $g(\nu)$: here $g(\nu) \sqsupset g(u)$ (see (54)). Thus, the only difference between (51) and (54) is about their silent post-suppositional test. It is worth noting that in (53), for the additive continuation, *I will also invite <u>some other people</u>*, this additive part (which is underlined) indicates an increase based on $g(u)$ (i.e., those you want to see), not based on $g(\nu)$ (i.e., those I will invite).

(54) $[\![(53)]\!] \Leftrightarrow \lambda g.\left\{ g^{\nu\mapsto y}_{u\mapsto x} \;\middle|\; \begin{array}{l} y = \Sigma y[\textsc{human}(y) \wedge \textsc{I-will-invite}(y)] \\ x = \Sigma x[\textsc{human}(x) \wedge \textsc{you-want-to-see}(x)] \end{array} \right\}$, if $g(\nu) \sqsupset g(u)$

(55) illustrates another kind of *wh*-conditionals, which involves two degree questions. (55) means that how much one eats determines how much one pays. Obviously, here the

two degree questions cannot have the same answer: the antecedent degree question addresses the measurement of food (e.g., counting how many plates of pizza one eats), while the consequent degree question addresses the measurement of money.

For (55), I assume that each degree question introduces two drefs: one in the domain of e (here x and y), and the other one in the domain of degrees (here d_1 and d_2). (56) shows that the most informative drefs are picked out: the mereologically maximal x and y, and the most informative amount measurement of x and y, i.e., d_1 and d_2. Obviously, d_1 and d_2 are the most informative analytical answers to the two degree questions in (55). A silent post-suppositional test **determine**$_{\nu_1,\nu_2}$ (see (57)) checks whether there is a context relevant function f that maps $g(\nu_1)$ to $g(\nu_2)$.

(55) chī duō-shǎo$^{u_1,\nu_1}$, fù duō-shǎo$^{u_2,\nu_2}$
eat how.much pay how.much
'How much one eats, how much one pays.' (adapted from Liu 2017)

(56) $$[\![(55)]\!] \Leftrightarrow \lambda g. \left\{ g^{\substack{\nu_2\mapsto d_2\\ \nu_1\mapsto d_1\\ u_2\mapsto y\\ u_1\mapsto x}} \;\middle|\; \begin{array}{l} d_2 = \mu_2(y) \\ d_1 = \mu_1(x) \\ y = \Sigma y[\textsc{money-one-pays}(y)] \\ x = \Sigma x[\textsc{food-one-eats}(x)] \end{array} \right\}, \text{if } \exists f. g(\nu_2) = f(g(\nu_1))$$

(57) $$\mathbf{determine}_{\nu_1,\nu_2} \overset{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s. \begin{cases} m(g) & \text{if } \exists f. g(\nu_2) = f(g(\nu_1)) \\ \varnothing & \text{otherwise} \end{cases}$$

Actually, the silent test that checks $g(\nu) = g(u)$ in (51) and the one that checks $g(\nu) \sqsupset g(u)$ in (54) can be considered special cases of the test **determine**$_{\nu_1,\nu_2}$ in (57). In all these Chinese *wh*-conditionals, the most informative analytical answer to the antecedent *wh*-clause contributes an independent variable, while the one to the consequent *wh*-clause is a dependent variable.

Finally, (58) illustrates a *wh*-conditional, the antecedent clause of which is a mention-some *wh*-question (see Xiang 2021b; see Section 4.5). The analysis in (59) shows that the current proposal can also handle this kind of *wh*-conditionals smoothly.

(58) Nǎr^u néng mǎi-dào jiǔ, wǒ jiù qù nǎr$^\nu$.
where^u can buy-reach liquor I then go where$^\nu$
'Where I can buy liquor, I will go where.' (Xiang 2021b: (92))

(59) $$[\![(58)]\!] \Leftrightarrow \lambda g.\left\{ g^{\substack{\nu\mapsto y\\ u\mapsto x}} \;\middle|\; \begin{array}{l} y = \Sigma y[\textsc{location}(y) \wedge \textsc{I-will-go}(y)] \\ x = f_{\text{choice}} x[\textsc{location}(x) \wedge \textsc{I-can-buy-liq.}(x)] \end{array} \right\}, \text{ if } g(\nu) \sqsupset g(u)$$

5.2 Short answers that are not individuals or entities

Under the current proposal, for *wh*-question *who*^{u} *smiled*, a good short answer like [*My Melody and Kuromi*]$_u$ provides additional information to the analytical answer *the one*(*s*) *who smiled*. We are actually not committed to considering [[My Melody and Kuromi]] a plural individual of type e. As shown in (60), we can analyze [[My Melody and Kuromi]] as a sum (i.e., plural individual, of type e), as a set (of type $\langle et \rangle$), or as a GQ (of type $\langle et, t\rangle$).

(60) a. **The short answer *My Melody and Kuromi* as a sum (of type e):** (=(23))

$$[\textbf{My-Melody} \oplus \textbf{Kuromi}]_u \overset{\text{def}}{=}$$
$$\lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } g(u) = \textbf{My-Melody} \oplus \textbf{Kuromi} \\ & (\text{or if } g(u) \sqsupseteq \textbf{My-Melody} \oplus \textbf{Kuromi}) \\ \varnothing & \text{otherwise} \end{cases}$$

b. **The short answer *My Melody and Kuromi* as a set (of type $\langle et \rangle$):**

$$\{\textbf{My-Melody}, \textbf{Kuromi}\}_u \overset{\text{def}}{=}$$
$$\lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } \{x' \mid x' \sqsubseteq_{\text{atom}} g(u)\} = \{\textbf{My-Melody}, \textbf{Kuromi}\} \\ & (\text{or if } \{x' \mid x' \sqsubseteq_{\text{atom}} g(u)\} \supseteq \{\textbf{My-Melody}, \textbf{Kuromi}\}) \\ \varnothing & \text{otherwise} \end{cases}$$

c. **The short answer *My Melody and Kuromi* as a GQ (of type $\langle et, t\rangle$):**

$$[\lambda P.[\textbf{My-Melody}(P) \wedge \textbf{Kuromi}(P)]]_u \overset{\text{def}}{=}$$
$$\lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } \{x' \mid x' \sqsubseteq_{\text{atom}} g(u)\} \in \lambda P.[\textbf{My-Melody}(P) \wedge \textbf{Kuromi}(P)] \\ & (\wedge |g(u)| = 2) \\ \varnothing & \text{otherwise} \end{cases}$$

The sum-based post-suppositional test in (60a) checks whether the maximal dref assigned to u (i.e., $g(u)$, *the one*(*s*) *who smiled*) is equal to (or includes) the sum **My-Melody** $\oplus$ **Kuromi**. The set-based post-suppositional test in (60b) checks whether the set $\{$**My-Melody**, **Kuromi**$\}$ is equal to (or a subset of) the set that includes all the atoms of $g(u)$. The GQ-based post-suppositional test in (60c) checks whether the set that includes all the atoms of $g(u)$ is a member of the set of sets $\lambda P.$**My-Melody**$(P) \wedge$ **Kuromi**(P). For this test (60c), we can include $|g(u)| = 2$ in the test to indicate that the short answer *My*

Melody and Kuromi is a complete answer.

Overall, these tests in (60) provide the same additional information about the analytical answer *the one(s) who smiled*, and how we formally characterize the meaning of *My Melody and Kuromi* does not matter. This flexibility means that a good short answer only needs to provide additional information about the analytical answer, but it does not need to be something that typically looks like a (potentially plural) individual of type e.

Meanwhile, the meaning of the most informative analytical answer, which is equivalent to the meaning of the *wh*-question, stays constant (here for (60), it is $[\![$who smiled$]\!]$, the maximal sum of smiling humans). We do not need to reanalyze or reformulate the meaning of a *wh*-question (e.g., lifting its type) or consider a *wh*-question ambiguous simply because we can provide additional information about the analytical answer in different ways, often with a short answer difficult to be considered of type e.

Below are some examples that are considered challenging in the literature (e.g., Jacobson 2016, Xiang 2021a). As illustrated in (62)–(64), in answering a *wh*-question like *Who*^{u} *smiled* (see (61)), various kinds of GQs can play the role of short answer and provide additional information to the analytical answer. These examples are not exhaustive. Oftentimes, formal analyses of the post-suppositional tests brought by these GQ-like expressions can be flexible, but basically capture the same additional information.

(61) Who^u smiled? $\rightsquigarrow$ the most informative analytical answer: the one(s) who smiled

$[\![\text{who}^u \text{ smiled}]\!] \Leftrightarrow \lambda g.\, \{g^{u\mapsto x} \mid x = \Sigma x[\textsc{human}(x) \wedge \textsc{smiled}(x)]\}$

(62) [Every kid]$_u$.

a. $\{y \mid \mathbf{kid}(y)\}_u \overset{\text{def}}{=}$ as a set

$$\lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } \{x' \mid x' \sqsubseteq_{\text{atom}} g(u)\} = \{y \mid \mathbf{kid}(y)\} \\ & \text{(or if } \{x' \mid x' \sqsubseteq_{\text{atom}} g(u)\} \supseteq \{y \mid \mathbf{kid}(y)\}) \\ \varnothing & \text{otherwise} \end{cases}$$

(i.e., checking whether the set including all kids is equal to (or a subset of) the set that includes all the atoms of $g(u)$)

b. $[\lambda P.\forall x[\mathbf{kid}(x) \to P(x)]]_u \overset{\text{def}}{=}$ as a GQ

$$\lambda m_{\langle s,st\rangle}.\lambda g_s.\begin{cases} m(g) & \text{if } \{x' \mid x' \sqsubseteq_{\text{atom}} g(u)\} \in \lambda P.\forall x[\mathbf{kid}(x) \to P(x)] \\ \varnothing & \text{otherwise} \end{cases}$$

(i.e., checking whether the set that includes all the atoms of $g(u)$ is a member of the set of sets $\lambda P.\forall x[\mathbf{kid}(x) \to P(x)]$; we can further include

$|g(u)| = |\{y \mid \mathbf{kid}(y)\}|$ to indicate that *every kid* is a complete answer)

(63) [Most kids]$_u$.

$$[\lambda P.[\ \underbrace{|\{y \mid \mathbf{kid}(y)\} \cap P|}_{\text{the cardinality of kids who } P} > \underbrace{|\{y \mid \mathbf{kid}(y)\} - P|}_{\text{the cardinality of kids who don't } P}\ ] \stackrel{\text{def}}{=} \qquad \text{as a GQ}$$

$$\lambda m_{\langle s,st\rangle}.\lambda g_s. \begin{cases} m(g) & \text{if } \{x' \mid x' \sqsubseteq_{\text{atom}} g(u)\} \in [\lambda P.[|\{y \mid \mathbf{kid}(y)\} \cap P| > |\{y \mid \mathbf{kid}(y)\} - P|] \\ \varnothing & \text{otherwise} \end{cases}$$

(i.e., checking whether the set containing all atoms in $g(u)$ (i.e., the set which means the property of being a smiling human) is a member of the set of properties P such that there are more kids who P than kids that don't P.)

(64) [No one but Junhyuk]$_u$.

a. $[\lambda P.\forall x[x \neq \mathbf{Junhyuk} \to \neg P(x)]]_u \stackrel{\text{def}}{=}$ as a GQ

$$\lambda m_{\langle s,st\rangle}.\lambda g_s. \begin{cases} m(g) & \text{if } \{x' \mid x' \sqsubseteq_{\text{atom}} g(u)\} \in \lambda P.\forall x[x \neq \mathbf{Junhyuk} \to \neg P(x)] \\ \varnothing & \text{otherwise} \end{cases}$$

(i.e., checking whether the set containing all atoms in $g(u)$ (i.e., the set which means the property of being a smiling human) is a member of the set of properties P such that no one other than Junhyuk P.)

b. $\mathbf{Junhyuk}_u \stackrel{\text{def}}{=} \lambda m_{\langle s,st\rangle}.\lambda g_s. \begin{cases} m(g) & \text{if } g(u) = \mathbf{Junhyuk} \\ \varnothing & \text{otherwise} \end{cases}$ as a sum

(i.e., checking whether $g(u)$ is equal to Junhyuk.)

Sometimes, for a specific short answer, special adjustments need to be made. For example, with regard to question (61), (65) is also an acceptable answer, but it seems that this answer is at odd with the idea that the maximal sum of smiling humans is assigned to u, which suggests that smiling humans exists.

For (65), I can follow Coppock and Beaver (2015)'s view and assume that as a definite description, the most informative analytical answer is essentially **predicative**, without a guarantee of existence (see Section 4.2; see (67) for Coppock and Beaver 2015's definition of *the*). Alternatively, I can consider that this answer *no one* provides a kind of amount measurement about $g(u)$, just like *at most 3 people* does (see (66)). For degree questions like *how many people will come*, *what is the temperature today*, *how much is the angle*, we also naturally provide short answers like *zero person*, *zero degrees Celsius*, and *zero degree*.[9]

[9]In fact, even if we naturally accept the idea that the amount of a sum of entities should be above zero, this idea might be part of our world knowledge. A negative amount of items is not linguistically or logically

(65) $[\text{No one}]_u$. $\rightsquigarrow$ checks whether $|g(u)| = 0$ good short answer to (61)

(66) $[\text{at most 3 people}]_u$. $\rightsquigarrow$ checks whether $|g(u)| \leq 3$ good short answer to (61)

(67) $[\![\text{the}]\!] \rightsquigarrow \lambda P.\lambda x.[\partial(|P| \leq 1) \wedge P(x)]$ (Coppock and Beaver 2015: p.395, (50))

Finally, here is an example with a disjunctive short answer. In (68a), the *wh*-item, *which*^{u} *kid*, imposes a uniqueness requirement. Thus in interpreting the *wh*-question (68a), for the maximal sum of smiling-kids assigned to u, we check whether the cardinality of $g(u)$ is 1. The analytical answer to this *wh*-question amounts to *the* (*unique*) *kid that smiled*.

A disjunctive expression *My Melody or Kuromi* provides additional information about this analytical answer. As shown in (68b), this post-suppositional test checks whether $g(u)$ (which is an atomic individual) is a member of the set $\{\textbf{My-Melody}, \textbf{Kuromi}\}$. Besides, for this disjunctive short answer, its connection with the domain of the *wh*-item is also checked by the part $\{\textbf{My-Melody}, \textbf{Kuromi}\} \subseteq \textbf{Domain}(g(u))$. Intuitively, if one of the disjuncts of the short answer is not a kid, the short answer would be considered infelicitous (see also e.g., Xiang 2021a).

(68) a. Q: Which^u kid smiled? $\rightsquigarrow$ the **unique** kid that smiled

$$\Leftrightarrow \underbrace{\mathbf{1}_u}_{\text{uniqueness tests}} [\underbrace{\mathbf{M}_u}_{\text{maximality}} \underbrace{[\![\text{some}^u \text{ kid(s) smiled}]\!]}_{\text{dref introduction}}]]$$

$$\Leftrightarrow \lambda g.\, \{g^{u\mapsto x} |\, x = \Sigma x[\textsc{kid}(x) \wedge \textsc{smiled}(x)]\}, \quad \underbrace{\text{if } |g(u)| = 1}_{\text{checking uniqueness}}$$

b. A: $[\text{My Melody or Kuromi}]_u$. Short answer with a disjunction as a set[10]

$$\{\textbf{My-Melody}, \textbf{Kuromi}\}_u \overset{\text{def}}{=}$$

$$\lambda m_{\langle s,st\rangle}.\lambda g_s. \begin{cases} m(g) & \text{if } g(u) \in \{\textbf{My-Melody}, \textbf{Kuromi}\} \\ & \wedge \{\textbf{My-Melody}, \textbf{Kuromi}\} \subseteq \textbf{Domain}(g(u)) \\ \varnothing & \text{otherwise} \end{cases}$$

5.3 Multi-*wh*-questions

For a sentence containing multiple modified numerals, Section 3.4 has discussed (i) a '**parallel interpretation strategy**', which results in the **cumulative** reading (see (30),

nonsensical and can naturally appear in fantasy stories. We also say sentences like *I have negative 3 dollars*.

[10] Zhang (2015) points out that both conjunctive (or *and*-related) and disjunctive (or *or*-related) expressions can be considered sets (or lists). The difference between them consists in how the elements in a set would be made use of in further computation: non-selectively (for *and*-related expressions) vs. selectively (or non-deterministically, for *or*-related expressions).

repeated here in (69)), and (ii) a '**non-parallel scope-taking strategy**', which results in the **pseudo-cumulative** reading (see (31), repeated here in (70)). These two kinds of readings correspond to different QUDs and different analytical answers to the QUDs:

(69) a. How many^u boys saw how many$^\nu$ movies? **Parallel** (= (30a))
The analytical answers include **2 items**: the cardinalities of maximal drefs
$|g(u)|: \underbrace{|\Sigma x[\textsc{boy}(x) \wedge \textsc{saw}(x,y)]|}_{\text{the cardinality of all the boys who saw movies}}, |g(\nu)|: \underbrace{|\Sigma y[\textsc{movie}(y) \wedge \textsc{saw}(x,y)]|}_{\text{the cardinality of all the movies seen by boys}}$
b. Exactly 3_u boys saw exactly 5_ν movies. **Cumulative** (= (4)/(30b))

(70) a. How many^u boys saw exactly 4 movies (between them)? (= (31a))
The analytical answer has 1 item: the cardinality of the unique maximal boy-sum [such that they saw a total of 4 movies between them] (see Fig. 2)
$|g(u)|: \underbrace{|\Sigma x[\textsc{boy}(x) \wedge |\Sigma y[\textsc{movie}(y) \wedge \textsc{saw}(x,y)]| = 4]|}_{\text{the cardinality of the unique maximal boy-sum who saw a total of 5 movies between them}}$
b. Exactly 3_u boys saw exactly 4 movies. **Pseudo-cumulative** (=(31b))

Here I show that similar to the data in (69) and (70), multi-*wh*-questions (see Dayal 2017 for a review) also involve a 'parallel strategy' and a 'non-parallel scope-taking strategy', leading to the **single-pair reading** and the **pair-list reading** (see (71)-(73)):

(71) Which girl read which book? Two readings: (72) and (73)

(72) The **single-pair reading** of the multi-*wh*-question (71):
a. **Context**: there is a unique girl reader, and she read a unique book. I want to have information about her and the book she read.
b. **A felicitous answer**: Moll read *Moll Flanders*.

(73) The **pair-list reading** of the multi-*wh*-question (71):
a. **Context**: there are some girl readers, and each of them read a single book. I want to have information about each girl reader the the book she read.
b. **A felicitous answer**: Anna read *Anna Karenina*; Emma read *Madame Bovary*; Jane read *Jane Eyre*.

5.3.1 The single-pair reading of a multi-*wh*-question

Just like the case of cumulative reading (see (69)), the **single-pair reading** for (72) is based on a 'parallel interpretation strategy', involving two maximality / answerhood operators simultaneously applied at the sentence level (i.e., the analytical answers include 2 items). The derivation in (74) is largely similar to that of the cumulative reading in (20) (and Haddock descriptions in (13), see Bumford 2017). Both *wh*-items carry a singular morpheme, which imposes a uniqueness requirement. Thus, there is a uniqueness test for each dref. That is to say, (74a) presupposes the existence of a unique girl reader and a unique book read by some girl. The analytical answers to this single-pair reading of (74a) are thus 2 items: (i) the unique girl reader, and (ii) the unique book read by her.

(74) a. Which^u girl read which$^\nu$ book? **Single-pair reading**: a parallel strategy

The analytical answers: the unique girl reader, the unique book read by her

$$[\![(74a)]\!] \Leftrightarrow \underbrace{\mathbf{1}_u[\mathbf{1}_\nu}_{\text{uniqueness tests}}\ [\underbrace{\mathbf{M}_u[\mathbf{M}_\nu}_{\text{maximality}}\ \underbrace{[\![\text{some}^u\ \text{girl(s) read some}^\nu\ \text{book(s)}]\!]}_{\text{dref introduction}}]]]]$$

$$\Leftrightarrow \lambda g\,.\left\{ g^{u\mapsto x}_{\nu\mapsto y} \;\middle|\; \begin{array}{l} y = \Sigma y[\textsc{book}(y) \wedge \textsc{read}(x,y)] \\ x = \Sigma x[\textsc{girl}(x) \wedge \textsc{read}(x,y)] \end{array} \right\}, \underbrace{\text{if } |g(u)| = 1, |g(\nu)| = 1}_{\text{checking uniqueness}}$$

b. Moll$_u$, *Moll Flanders*$_\nu$ **Short answer** corresponding to (72b)

$\rightsquigarrow$ checks whether $g(u) = \textbf{Moll} \wedge g(\nu) = \textbf{\textit{M.F.}}$

c. Moll$_u$ read *Moll Flanders*$_\nu$. **Propositional answer** (72b)

$$\textbf{Moll}_u[\textbf{\textit{M.F.}}_\nu\ \underbrace{[\mathbf{1}_u[\mathbf{1}_\nu[\mathbf{M}_u[\mathbf{M}_\nu[\![\text{some}^u\ \text{girl(s) read some}^\nu\ \text{book(s)}]\!]]]]]}_{\text{the meaning of the single-pair reading of (74a), i.e., its analytical answers}}]$$

$$\Leftrightarrow \lambda g\,.\left\{ g^{u\mapsto x}_{\nu\mapsto y} \;\middle|\; \begin{array}{l} y = \Sigma y[\textsc{book}(y) \wedge \textsc{read}(x,y)] \\ x = \Sigma x[\textsc{girl}(x) \wedge \textsc{read}(x,y)] \end{array} \right\}, \text{if } x = \textbf{Moll} \wedge y = \textbf{\textit{M.F.}}$$

5.3.2 The pair-list reading of a multi-*wh*-question

For the **pair-list reading**, there are a few interesting things to observe. **First**, although the two *wh*-items in (71) carry a singular morpheme, (71) can be felicitously used in a context where there are multiple girl readers and multiple books read by girls (see (73a)). The plurality of the girls and books involved in the pair-list reading is also evidenced by the data of cross-sentential anaphora (see the opposite patterns of (75) vs. (76)). Thus, for the pair-list reading of (71)/(76), *which^u girl* actually introduces a **potentially plural dref**.

(75) Which^u girl read which$^\nu$ book? **Single-pair reading** (see the context in (72a))

a. Does she$_u$ like it$_\nu$?

b. #Do they$_u$ like them$_\nu$?

(76) Which^u girl read which$^\nu$ book? **Pair-list reading** (see the context in (73a))

a. #Does she$_u$ like it$_\nu$?

b. Do they$_u$ like them$_\nu$ / their$_u$ book(s) / # it$_\nu$?

Second, the pair-list reading of (71)/(76) pattern with data like (77) in two aspects: (i) the singular morphemes of the two DPs involved, and (ii) the plural morphemes used in cross-sentential anaphora. This parallelism suggests that (i) the singular morpheme of *which*^{u} *girl* in the pair-list reading is due to a silent distributivity operator, and (ii) the singular morpheme of *which*^{u} *book* is at the level of atomic girl readers, indicating that each girl reader is mapped to a singular book, as illustrated in (78).

(77) Each^u girl carried a$^\nu$ puppy. They$_u$ like their$_u$ puppi(es) / them$_\nu$.

(78) Which^u [DIST girl read which$^\nu$ book] (=(71)/(76))

In other words, as illustrated in (79), we can consider that there is a **function** from the set of atomic girl readers to the set of books (see e.g., Schlenker 2006, Brasoveanu 2011, Bumford 2015, Dayal 2016 for discussion on functional dependency). Thus, for the pair-list reading of (71)/(76), *which*^{u} *girl* introduces a potentially plural individual dref, while *which*$^\nu$*book* can be considered **introducing a dref that is a function**: among all the relevant girls, each atomic girl x read a single book, $f(x)$.

(79) **Representing the function for the answer (73b) as a set of ordered pairs**:
f = {⟨Anna, *Anna Karenina*⟩, ⟨Emma, *Madame Bovary*⟩, ⟨Jane, *Jane Eyre*⟩}

There seems a problem with this assumption of a silent distributivity operator (for the pair-list reading in (78)). For a similar sentence like (80), why cannot we also assume a silent distributivity operator and have a functional reading? The functional reading for (80) is empirically unattested, as confirmed by how cross-sentential anaphora are used (see (80a) vs. (80b)). This seeming over-generation is explained by the next observation.

(80) Which^u girl read a$^\nu$ book? $\not\rightsquigarrow$ Which^u [DIST girl read a$^\nu$ book]?
Unattested reading: who are the girls [such that each one x read a book, $f(x)$]

a. #Do they$_u$ like them$_\nu$? $\rightsquigarrow$ *Which*^{u} *girl* in (80) cannot introduce a plural dref

b. Does she like it?

The **third** observation is about the similarity between the pseudo-cumulative reading in (70) and the pair-list reading. Both constructions involve non-parallel scope-taking, and eventually, their analytical answer consists in only one thing, not two things (cf. the genuine cumulative reading in (69) and the single-pair reading in (74)). For the pair-list reading of (78), the analytical answer is only about the function introduced by *which*$^{\nu}$ *book*, not about the girl-sum introduced by *which*^{u} *girl*. This is hinted by what a typical felicitous answer to the pair-list reading looks like (see (73b) and also (79)).

In (81a), the pseudo-cumulative reading corresponds to a QUD containing only one *wh*-item. In the question and its analytical answer, the maximality operator brought by *exactly 5 movies* takes narrow scope, working as part of the restriction for defining relevant boy-sums. Similarly, for the pair-list reading (see (81b)), the maximality operator brought by *which*^{u} *girl* takes narrow scope, working as part of the restriction for function drefs. Eventually, the underlying QUD and analytical answer of (81b) address just a function.

(82) provides empirical support for the non-parallel scope-taking analysis in (81b). If *which*$^{\nu}$ *girl* and *which*$^{\nu}$ *book* restrict each other (i.e., (i) the maximal relevant girl-sum and (ii) the function that maps each atomic girl-reader to the unique book she read are selected simultaneously), then the pair-list reading is predicted to be good under the context in (82a): the maximal relevant girl-sum would only include Anna and Jane, who read one book each, and exclude Emma, who read 2 books. This prediction is not borne out. The intuitive infelicity of using (81b) under the context (82a) indicates that the selection of the maximal relevant girl-sum should be irrespective of the selection of the function (along with its singularity requirement). In other words, during the selection of the maximal relevant girl-sum, the function introduced by *which*$^{\nu}$ *book* should not be involved, and the selected maximal relevant girl-sum should include all the girls who read any book.

(81) **Pseudo-cumulative reading vs. pair-list reading: both involve scope-taking**

a. Exactly 3 boys saw exactly 5 movies (between them). **Pseudo-cumulative**
How many boys saw exactly 5 movies (between them)? Underlying QUD
Analytical answer: the cardinality of the unique maximal boy-sum [such that they saw a total of 5 movies between them] (see (31)/(70))

b. Which^{u} girl read which$^{\nu}$ book? **Pair-list reading**
≈ Which^{u} girls read books? Which$^{\nu}$ book did each of them$_{u}$ read?
Analytical answer: the most informative function f [such that each of

the girls who read books, x, read a book, $f(x)$, and $|f(x)| = 1$]

(82) a. **(81b) cannot be felicitously used**: the singularity of *which*$^{\nu}$ *book* is violated
Context: Anna only read one book, *Anna Karenina*. Jane also only read one book, *Jane Eyre*. Emma read two books, *Emma* and *Madame Bovary*.

b. **(81b) can be felicitously used**:
Context: Every girl who read any book only read a singular book.

A further consequence of this non-parallel scope-taking analysis is that, in the pair-list reading, given that the introduction and selection of girl-sum drefs are irrespective of the function part, the assumed silent distributivity operator should be attributed to the function-related *wh*-item, here *which*$^{\nu}$ *book* (see the paraphrase in (81b)) (i.e., the function assigned to ν has the requirement that its domain is a set of atoms). This explains why a functional reading is unavailable for (80). In (80), the lack of a function-related *wh*-item leads to the unavailability of such a silent distributivity operator. Thus, (80) cannot be analyzed in the same way as the pair-list reading. On the other hand, (83) has an attested functional reading: it is similar to the second part of the paraphrase in (81b), asking about the function that maps each girl in the domain to a singular book.[11]

(83) Which$^{\nu}$ book did every girl read? **A functional reading is possible**
$\rightsquigarrow$ What is the function f such that every girl x read $f(x)$-book?

Based on the above observations, (84) shows the derivation of the pair-list reading:

(84) Which^{u} [DIST girl read which$^{\nu}$ book] **Pair-list reading** of (71)/(76)

$$[\![(84)]\!] \Leftrightarrow \mathbf{1}_{\nu}[\mathbf{M}_{\nu}[\mathbf{M}_{u}[\text{some}^{u}\ \text{girl(s) (each) read some}^{\nu}\ \text{book}]]]$$

$$\Leftrightarrow \mathbf{1}_{\nu}[\mathbf{M}_{\nu}[\mathbf{M}_{u}[\lambda g.\left\{ g^{u\mapsto x}_{\nu\mapsto f} \;\middle|\; \begin{array}{l} \forall x' \sqsubseteq_{\text{atom}} x[\textsc{book}(f(x')) \wedge \textsc{read}(x, f(x'))] \\ \textsc{girl}(x) \end{array} \right\}]]]$$

$$\Leftrightarrow$$

[11] Question (83) has a quantificational subject and is called **QiQ-question** (quantification into questions). (ia) and (ib) illustrate two ways to answer this QiQ-question (83). Under the current analysis, both answer is based on the scope-taking '*which*$^{\nu}$ *book* > *every girl*' in interpreting (83). (ia) can be considered a special case of the functional answer in (ib): the function maps every girl in the domain to the same book.

(i) a. Every girl read *Norwegian Wood*. **The same book**
b. Anna read *Anna Karenina*; Emma read *Madame Bovary*; Jane read *Jane Eyre*. **Pair-list**

$$\mathbf{1}_\nu[\mathbf{M}_\nu[\lambda g\,.\left\{ g^{\nu\mapsto f}_{u\mapsto x} \,\middle|\, \begin{array}{l} \forall x' \sqsubseteq_{\text{atom}} x[\text{BOOK}(f(x')) \wedge \text{READ}(x, f(x'))] \\ x = \underbrace{\Sigma x[\text{GIRL}(x) \wedge \forall x' \sqsubseteq_{\text{atom}} x[\text{BOOK}(f(x')) \wedge \text{READ}(x, f(x'))]]}_{\text{the maximal girl-sum s.t. each atomic member read some books (i.e., all the girls who read books)}} \end{array}\right\}]]$$

$$\Leftrightarrow \mathbf{1}_\nu[\lambda g\,.\left\{ g^{\nu\mapsto f}_{u\mapsto x} \,\middle|\, \begin{array}{l} \forall x' \sqsubseteq_{\text{atom}} x[f(x') = \underbrace{\Sigma y[\text{BOOK}(y) \wedge \text{READ}(x', y)]}_{\text{the definite } f \text{ that maps } x' \text{ to the maximal book-sum } x' \text{ read}}] \\ x = \underbrace{\Sigma x[\text{GIRL}(x) \wedge \forall x' \sqsubseteq_{\text{atom}} x[\text{BOOK}(f(x')) \wedge \text{READ}(x, f(x'))]]}_{\text{the maximal girl-sum s.t. each atomic member read some books}} \end{array}\right\}]$$

Finally, $\mathbf{1}_\nu$ checks the singularity requirement brought by *which*$^\nu$ *book*: i.e., whether $\forall x' \sqsubseteq_{\text{atom}} g(u)[|g(\nu)(x')| = 1]$

In (84), *which*^{u} *girl* introduces a potentially plural individual dref, x, and *which*$^\nu$ *book* introduces a function dref, f, and a restriction involving distributivity is also added.

$\mathbf{M}_u$, the maximality operator associated with *which*^{u} *girl*, selects out the maximal girl-sum x such that its each atom x' read some books. $\mathbf{M}_\nu$, the maximality operator associated with *which*$^\nu$ *book*, selects out the most informative function, i.e., the one that maps each atomic girl reader x' to the maximal book-sum x' read, $f(x')$.

The singularity of *which*^{u} *girl* is naturally guaranteed by the use of the hidden distributivity operator brought by the function, while the singularity requirement of *which*$^\nu$ *book* needs to be checked now, i.e., $\mathbf{1}_\nu$ checks whether each value (i.e., book-sum) in the range of the selected function has the cardinality of 1. For a felicitous answer like (73b), we further apply a post-suppositional test like the one shown in (79), i.e., whether $f = \{\langle \text{Anna}, \textit{Anna Karenina}\rangle, \langle \text{Emma}, \textit{Madame Bovary}\rangle, \langle \text{Jane}, \textit{Jane Eyre}\rangle\}$.

Under the context (82a), the derivation ends with an empty set at the step of checking $\mathbf{1}_\nu$, because $|f(\mathbf{Emma})| = 2$, instead of 1.

5.4 Strong, weak, and intermediate exhaustivity

The notion of the maximally informative analytical answer is also useful in understanding phenomena involving embedded *wh*-questions.

The underlined parts in (85) all have the same meaning: i.e., the maximally informative analytical answer to *how tall Junhyuk is*, which is also equivalent to the meaning of the concealed question in (86), *the height of Junhyuk*. Section 2.2 has shown that the meaning proper of expressions like ⟦How tall is Junhyuk⟧ or ⟦the height of Junhyuk⟧ is L-trivial, calling for additional information at the global level. Thus, in (85) and (86), the non-underlined parts should have provided additional information that solves the local

L-analyticity of the underlined part at the global level, leading to acceptable sentences. In this sense, in (85) and (86), the non-underlined parts play a role similar to cardinality information in the cumulative reading or good, felicitous short answers to a *wh*-question. Here I focus on the non-underlined, embedding part in (85a) and (86a): *Kuromi knows*.

(85) How tall is Junhyuk? **Matrix degree question** $\rightsquigarrow$ HEIGHT(Junhyuk)

a. Kuromi knows how tall Junhyuk is. **As the complement clause of *know***

b. Brian is about 5 cm taller than Junhyuk is ~~tall~~. **As a *than*-clause**
($\rightsquigarrow$ HEIGHT(Brian) − HEIGHT(Junhyuk) $\approx$ 5 cm) (see e.g., Zhang and Ling 2021)

(86) **Concealed question** (see Section 4.6)

a. Kuromi knows the height of Junhyuk. (= (85a))

b. Brian is about 5 cm taller than the height of Junhyuk. (= (85b))

Among various theories on question semantics, Partition Semantics (Groenendijk and Stokhof 1982, 1984, 1990a) is motivated by a distinction between a **strong** vs. a **weak** exhaustive reading in interpreting attitude-reporting predicate *know*. Moreover, Cremers and Chemla (2016) has provided experimental evidence showing that (i) the strong exhaustive reading does exist, but is not prominent, and (ii) the most prominent reading is an **intermediate** exhaustive reading.

Under the **weak** exhaustive reading, (87) means that Kuromi has only the complete knowledge about all those who came: i.e., if x came, Kuromi knows that x came. Under the **strong** exhaustive reading, (87) means that Kuromi has the complete knowledge about everyone in the domain, including all those who came and all those who didn't: i.e., if x came, Kuromi knows that x came, and if x didn't come, Kuromi knows that x didn't come. Under the **intermediate** exhaustive reading, (87) means that Kuromi has the complete knowledge about all those who came and has no false beliefs about anyone else.

(87) Kuromi knows who^u came.

	for those who came	**for those who didn't come**
weak	Kuromi knows they came (true belief)	Kuromi might have false or no beliefs about them /
strong	Kuromi knows they came (true belief)	Kuromi knows they didn't come (true belief)
intermediate	Kuromi knows they came (true belief)	Kuromi does not have false beliefs about them (no false belief)

The current proposal can be extended to account for these three readings.[12] As shown in (88), the embedded *wh*-question in (87) is analyzed in the same way as a matrix *wh*-question, with $\mathbf{M}_u$ picking out the maximal sum of all those who came to assign to u.

(88) $[\![(87)]\!] \Leftrightarrow$ **Kuromi-knows**$_u[\mathbf{M}_u[[\![\text{some}^u(\text{people}) \text{ came}]\!]]]$
$\mathbf{M}_u[[\![\text{some}^u(\text{people}) \text{ came}]\!]] \Leftrightarrow \lambda g.\ \{g^{u\mapsto x} |\ x = \Sigma x[\textsc{human}(x) \wedge \textsc{came}(x)]\}$

Then the part **Kuromi-knows**$_u$ works as a post-suppositional test, providing additional information on $g(u)$, addressing the connection between Kuromi's knowledge and this maximally informative analytical answer.

Knowledge can be considered **justified true belief** (see e.g., Ichikawa and Steup 2018). For the current purpose, I ignore the part about justification and represent Kuromi's knowledge as a **measure function**. As shown in (89), this measure function takes an item in a relevant domain (e.g., a domain of humans for (87), or a domain of height degrees for (85a)/(86a)), x, as input, and measures the **(in)consistency** of Kuromi's belief about x with what x is actually like. Here 'what x is actually like' is interpreted as whether x is part of $g(u)$ (or for a domain of degrees, whether $x \leq g(u)$).

(89) **Knowledge as a measure function**:

a. If Kuromi's belief about x is **consistent** with what x is actually like, **Kuromi-knows**$(x) = 1$. $\rightsquigarrow$ Kuromi has knowledge about x

b. If Kuromi's belief about x is **inconsistent** with what x is actually like, **Kuromi-knows**$(x) = 0$. $\rightsquigarrow$ Kuromi has false belief about x

(90) and (91) show the analysis of the three readings in the domains of individuals and degrees, respectively. The **weak** exhaustive reading means that Kuromi has knowledge about any item that is not informatively stronger than $g(u)$ (see (90a) and (91a)). The **strong** exhaustive reading means that Kuromi has knowledge about any item in the domain (see (90b) and (91b)). The **intermediate** reading means that (i) Kuromi has knowledge about any item that is not informatively stronger than $g(u)$, and (ii) it is not the case that Kuromi has false belief about anything in the domain (see (90c) and (91c)).

(90) The domain of the *wh*-item is a **domain of individuals**:

a. **Weak exhaustivity reading**:

[12] However, it is not the task of the current paper to figure out whether *know* is lexically ambiguous, or whether some of these readings are due to pragmatic meaning strengthening.

$[\textbf{Kuromi-knows}_{\text{weak}}]_u \overset{\text{def}}{=} \lambda m.\lambda g.m(g)$ if $\forall x \sqsubseteq g(u)[\textbf{Kuromi-knows}(x) = 1]$
(i.e., for any x that is a part $g(u)$, Kuromi knows that x is part of $g(u)$.)

b. **Strong exhaustivity reading**:
$[\textbf{Kuromi-knows}_{\text{strong}}]_u \overset{\text{def}}{=} \lambda m.\lambda g.m(g)$ if
$\forall x \in \textbf{Domain}(g(u))[\textbf{Kuromi-knows}(x) = 1]$
(i.e., for any x in the domain of the *wh*-item, Kuromi knows whether $x \sqsubseteq g(u)$.)

c. **Intermediate exhaustivity reading**:
$[\textbf{Kuromi-knows}_{\text{in}}]_u \overset{\text{def}}{=} \lambda m.\lambda g.m(g)$ if $\forall x \sqsubseteq g(u)[\textbf{Kuromi-knows}(x) = 1] \wedge \forall x \in \textbf{Domain}(g(u))[\neg[\textbf{Kuromi-knows}(x) = 0]]$
(i.e., (i) for any x that is a part $g(u)$, Kuromi knows that $x \sqsubseteq g(u)$, and (ii) for any x in the domain of the *wh*-item, Kuromi has no false belief about x.)

(91) The domain of the *wh*-item is a **domain of degrees**:

a. **Weak exhaustivity reading**:
$[\textbf{Kuromi-knows}_{\text{weak}}]_u \overset{\text{def}}{=} \lambda m.\lambda g.m(g)$ if $\forall x \leq g(u)[\textbf{Kuromi-knows}(x) = 1]$
(i.e., for any degree x not exceeding $g(u)$, Kuromi knows $x \leq g(u)$.)

b. **Strong exhaustivity reading**:
$[\textbf{Kuromi-knows}_{\text{strong}}]_u \overset{\text{def}}{=} \lambda m.\lambda g.m(g)$ if
$\forall x \in \textbf{Domain}(g(u))[\textbf{Kuromi-knows}(x) = 1]$
(i.e., for any x in the domain of the *wh*-item, Kuromi knows whether $x \leq g(u)$.)

c. **Intermediate exhaustivity reading**:
$[\textbf{Kuromi-knows}_{\text{in}}]_u \overset{\text{def}}{=} \lambda m.\lambda g.m(g)$ if $\forall x \leq g(u)[\textbf{Kuromi-knows}(x) = 1] \wedge \forall x \in \textbf{Domain}(g(u))[\neg[\textbf{Kuromi-knows}(x) = 0]]$
(i.e., (i) for any degree x not exceeding $g(u)$, Kuromi knows $x \leq g(u)$, and (ii) for any x in the domain of the *wh*-item, Kuromi has no false belief about x.)

Obviously, (90) accounts for the empirical pattern shown in (87), with regard to a domain of individuals. (91) and (92) show that the knowledge about a domain of degrees can be accounted for in exactly the same way.

(92) Kuromi knows how tall Junhyuk is / the height of Junhyuk. (= (85a)/(86a))

a. **Weak reading**: for any height degree $d \leq$ HEIGHT(Junhyuk), Kuromi knows that the height of Junhyuk reaches d.

b. **Strong reading**: for any height degree d, Kuromi knows whether the height of Junhyuk reaches d.

c. **Intermediate reading**: (i) for any height degree $d \leq \textsc{height}(\text{Junhyuk})$, Kuromi knows that $d \leq \textsc{height}(\text{Junhyuk})$, and (ii) for any height d' above $\textsc{height}(\text{Junhyuk})$, Kuromi does not wrongly believe $d \leq \textsc{height}(\text{Junhyuk})$.

To capture the strong exhaustive reading, Partition Semantics analyzes a question as a partition on possible worlds. For (87), the strong exhaustive reading means that Kuromi knows exactly which possible world(s) she is at: e.g., possible worlds where only Cinnamoroll and My Melody came, and all other people didn't. Thus possible worlds where Cinnamoroll, My Melody, and Baku came should not be included.

Under the current analysis, crucially, we don't need to consider the specific individuals who came in a certain possible world (see (87) and (90)), the specific height of Junhyuk in a certain possible world (see (91) and (92)), or the specific possible worlds the attitude-holder (here Kuromi) is located at. As mentioned in Section 4.2, the meaning proper of the analytical answer (e.g., *all those who came* for (87), *the height of Junhyuk* for (92)) is independent from possible worlds.

Even if additional information about the analytical answer varies from world to world, (i) the analytical answer itself and (ii) the way how somebody's knowledge is connected to this analytical answer (see (89)) are stable across different possible worlds. Another way to look at this is that the meaning of *Kuromi knows* is also analytical: it means the analytical answer to *what Kuromi knows*. (89) amounts to checking how the two analytical answers are consistent with each other. Thus, the meaning of sentences like (87) and (92) remains stable from world to world, and the current analysis captures this stability.

The current analysis about a domain of individuals (see (90)) also makes predictions about how to interpret embedded mention-some *wh*-questions (see (93). Intuitively, the most natural reading here seems the intermediate reading in (93c), which is consistent with Cremers and Chemla (2016). Detailed investigations are for future research.

(93) ***Know* with embedded mention-some *wh*-questions**:
Context: All the places where people can get good cheese are A, B, and C. Kuromi knows that she can get good cheese at A and B.
Sentence: Kuromi knows where she can get good cheese. (Here $g(u) = A \oplus B$)
The QUD is fully resolved.

a. **Weak reading**: for any $x \sqsubseteq g(u)$, $\textbf{Kuromi-knows}(x) = 1$, i.e., Kuromi knows that she can get good cheese at A and B.

b. **Strong / mention-all reading**: for any x in the domain, **Kuromi-knows**$(x) = 1$, i.e., Kuromi knows all the places where she can / cannot get good cheese.

c. **Intermediate reading**: (i) for any $x \sqsubseteq g(u)$, **Kuromi-knows**$(x) = 1$, i.e., Kuromi knows that she can get good cheese at A and B, and (ii) for any x in the domain, $\neg[$**Kuromi-knows**$(x) = 0]$, i.e., Kuromi does not wrongly believe that she cannot get good cheese at C or she can get good cheese elsewhere.

5.5 Quantificational variability

Based on the discussion of ⟦Kuromi knows⟧ in Section 5.4, **quantificational variability** (see Berman 1991) can be accounted for in the same way, as illustrated in (94)-(96).

It seems that ⟦Kuromi partly knows⟧ only has a weak reading (see (95)), while for ⟦Kuromi mostly knows⟧, there seems a weak and a strong reading (see (96)). Whether the predicted readings are all attested needs more experimental investigations in future work. More complex cases that involve embedded pair-list *wh*-questions (see Section 5.3) are also left for another occasion (see also Xiang 2023 for discussion).

(94) **Quantificational variability**:

a. Kuromi partly knows <u>who^u came</u>.

b. Kuromi mostly knows <u>who^u came</u>.

(95) $\textbf{Kuromi-partly-knows}_u \stackrel{\text{def}}{=} \lambda m.\lambda g.m(g)$ if $\exists x[x \sqsubseteq g(u) \wedge \textbf{Kuromi-knows}(x) = 1]$
(corresponding to the weak exhaustive reading in (90a))

(96) $\textbf{Kuromi-mostly-knows}_u \stackrel{\text{def}}{=} \lambda m.\lambda g.m(g)$ if $\exists x'[x' \sqsubseteq g(u) \wedge \mathfrak{Know}_{\mathfrak{M}}(x' \sqsubseteq g(u))]$

a. **Weak**: checks whether for most $x \sqsubseteq g(u)$, $\textbf{Kuromi-knows}(x) = 1$

b. **Strong**: checks whether for most $x \in \textbf{Domain}(g(u))$, $\textbf{Kuromi-knows}(x) = 1$

5.6 Question coordination

Under the current proposal, **question coordination** (see e.g., Xiang 2021b) can also be accounted for smoothly, as illustrated in (97)-(99). In (98), the two *wh*-items each introduce a dref and different restrictions are applied to the two drefs respectively, and then two **M** operators are applied, selecting out the maximal drefs. Finally, (99) shows that Jenny has the (weak, strong, or intermediate) exhaustive knowledge about these two maximal drefs. In her knowledge, each dref is tracked separately.

(97) Jenny knows who^{u_1} voted for Andy and who^{u_2} voted for Bill. (Xiang 2021b: (53))

(98) $[\![(97)]\!] \Leftrightarrow$

$\textbf{Jenny-knows}_{u_1,u_2}[[\mathbf{M}_{u_1}[\![\text{some}^{u_1}(\text{human}) \text{ voted for A}]\!]], [\mathbf{M}_{u_2}[\![\text{some}^{u_2}(\text{human}) \text{ voted for B}]\!]]]$

$\Leftrightarrow \textbf{Jenny-knows}_{u_1,u_2}[\lambda g.\left\{ g^{u_1 \mapsto x}_{u_2 \mapsto y} \middle| \begin{array}{l} y = \Sigma y[\textsc{human}(y) \wedge \textsc{voted}(y, \text{Bill})] \\ x = \Sigma x[\textsc{human}(x) \wedge \textsc{voted}(x, \text{Andy})] \end{array} \right\}]$

(99) a. **Weak exhaustivity reading**:
$[\textbf{Jenny-knows}_{\text{weak}}]_{u_1,u_2,\ldots} \overset{\text{def}}{=} \lambda m.\lambda g.m(g)$ if for each variable $u_i \in \{u_1, u_2, \ldots\}$, $\forall x \sqsubseteq g(u_i)[\textbf{Jenny-knows}(x) = 1]$
(i.e., for any x that is a part $g(u_i)$, Jenny knows that x is part of $g(u_i)$.)

b. **Strong exhaustivity reading**:
$[\textbf{Jenny-knows}_{\text{strong}}]_{u_1,u_2,\ldots} \overset{\text{def}}{=} \lambda m.\lambda g.m(g)$ if for each variable $u_i \in \{u_1, u_2, \ldots\}$, $\forall x \in \textbf{Domain}(g(u_i))[\textbf{Jenny-knows}(x) = 1]$
(i.e., for any x in the domain of the *wh*-item, Jenny knows whether $x \sqsubseteq g(u_i)$.)

c. **Intermediate exhaustivity reading**:
$[\textbf{Jenny-knows}_{\text{in}}]_{u_1,u_2,\ldots} \overset{\text{def}}{=} \lambda m.\lambda g.m(g)$ if for each variable $u_i \in \{u_1, u_2, \ldots\}$, $\forall x \sqsubseteq g(u_i)[\textbf{Jenny-knows}(x) = 1] \wedge \forall x \in \textbf{Domain}(g(u_i))[\neg[\textbf{Jenny-knows}(x) = 0]]$
(i.e., (i) for any x that is a part $g(u_i)$, Jenny knows that $x \sqsubseteq g(u_i)$, and (ii) for any x in the domain of its *wh*-item, Jenny has no false belief about x.)

Obviously, when the analyses proposed in Sections 5.3 and 5.4 are combined, we can also account for the coordination between a single *wh*-question and a multi-*wh*-question (see (100)). Eventually, the consistency between (i) the analytical answer to each of the coordinated *wh*-clauses and (ii) what Jenny knows gets checked.

(100) Jenny knows who^{u_1} came and who^{u_2} bought what^{u_3}. (Xiang 2021b: (110))

The current analysis can also account for the coordination between an embedded clausal *wh*-question (a CP) and a concealed question (a DP) (see (101); see Section 4.6).

(101) Kuromi knows how many^{u} people will come and the$^{\nu}$ number of pizzas.
(= Kuromi knows how many^{u} people will come and how many$^{\nu}$ pizzas there are.)

5.7 Question dependency

Section 4.2 has shown that the current proposal inherits the spirit of Karttunen (1977): A question denotes its **true** answer(s). The phenomena of **question dependency** (see (102)) seem to challenge Karttunen (1977)'s 'true answer' view and support Hamblin (1973)'s 'possible answer' view: A question denotes its **possible** propositional answers (see (103)). According to our intuition, the part *where is Mary* in (102) seems to denote a **Hamblin set**, i.e., a set of possible answers that address where Mary is (see (103)).

(102) **Question dependency** (see e.g., Dayal 2016: Section 2.2.2, (33)–(34))

a. What does John think? Where is Mary? **Indirect dependency**

b. Where does John think Mary is? **Direct dependency**

(103) **Hamblin (1973)'s 'possible answer' view**: $\rightsquigarrow$ a set of possible answers

$[\![\text{where is Mary}]\!] = \{\lambda w.\textsc{At}_w(\text{Mary}, x) \mid x \in \lambda x.\textsc{location}(x)\}$ **Hamblin set**

Syntactically, there are two types of question dependency: **indirect dependency** (see (102a)) and **direct dependency** (see (102b)) . Semantically, they have the same meaning. Based on their syntactic differences, Dayal (1994, 2016) advocate distinct analyses to derive their meaning. Here I show how to derive the meaning of (102a) and (102b) respectively, and that eventually, the proposed analysis is still in line with Karttunen (1977).

(104) $[\![(102b)]\!] = [\![\text{where}^u \text{ does John think Mary is}]\!] \Leftrightarrow$

$\lambda g.\{g^{u\mapsto x} \mid x = \Sigma x[\textsc{location}(x) \wedge \textsc{John-thinks}(\lambda w.\textsc{At}_w(\text{Mary}, x))]\}$

$\mathbf{M}_u$

$[\![\text{John thinks Mary is somewhere}^u]\!] \Leftrightarrow$

$\lambda g.\{g^{u\mapsto x} \mid \textsc{location}(x), \textsc{John-thinks}(\lambda w.\textsc{At}_w(\text{Mary}, x))\}$

John thinks

$\langle st, t\rangle$

$\lambda w.$

Mary is where^u in w

As shown in (104), the derivation of direct dependency is straightforward. *Wh*-item *where*^{u} introduces a dref (which is a location), and the application of the maximality operator $\mathbf{M}_u$ is at the matrix level, yielding the most informative analytical answer.

Although syntactically, attitude-reporting predicates *know* and *think* both take a CP as their complement, there are huge differences between the semantics of their complement clauses (see more discussion in Section 6.2). Our intuition for the sentences in (105) and (106) indicate that *John knows* and *John thinks* work differently. *John knows* provides additional information about the analytical answer to the embedded *wh*-question (see (105a) and Section 5.4). For *John thinks*, there is no embedded *wh*-question in the first place (see (106)). In other words, the embedded part *where Mary is* cannot be considered a question, and thus, its interpretation does not amount to the interpretation of a question.

In (104), $[\![$John thinks$]\!]$ is considered of type $\langle st, t\rangle$, restricting items of type $\langle st\rangle$, and the embedded CP complement is of type $\langle st\rangle$. Eventually, in (104), u is assigned to the most informative dref x such that John thinks Mary is in x, i.e., the analytical answer here is 'the location where John thinks Mary is at', not 'the location where Mary is at'.

(105) **The complement of *know* can be a *wh*-question**
$\rightsquigarrow$ the maximality / answerhood operator $\mathbf{M}_u$ is at the embedded-clause level

a. John <u>knows</u> where^u Mary is. $\mathbf{M}_u$ is at the embedded clause
$\rightsquigarrow$John knows $\mathbf{M}_u[\![$Mary is somewhere$^u]\!]$
($\rightsquigarrow$ **John-knows**$_u$ checks the consistency between (i) where Mary is and (ii) what John knows, see (89) and (90) in Section 5.4)

b. *Where^u does John <u>know</u> Mary is? $\mathbf{M}_u$ cannot be at the matrix level

(106) **The complement of *think* cannot be a *wh*-question**
$\rightsquigarrow$ the maximality / answerhood operator $\mathbf{M}_u$ is at the matrix-clause level

a. Where^u does John <u>think</u> Mary is?
$\rightsquigarrow$ $\mathbf{M}_u[\![$John thinks Mary is somewhere$^u]\!]$ $\mathbf{M}_u$ is at the matrix level

b. *John <u>thinks</u> where^u Mary is. $\mathbf{M}_u$ cannot be at the embedded clause

For the case of indirect dependency (see (107)), I propose that *what*$^\nu$ introduces a proposition dref of type $\langle st\rangle$ (see Step 1), and *where*^{u} introduces a location dref of type e. In (102a), the part *what*$^\nu$ *does John think* denotes its analytical answer, i.e., all what John thinks (see Step 2). The part *where*^{u} *is Mary* works as a post-suppositional test and provides further information on $g(\nu)$ (i.e., all what John thinks, see Step 3), while at the same time, a location dref is introduced. The rest is similar to that of direct dependency. The maximality operator $\mathbf{M}_u$ is applied at the matrix level. Thus, (102a) also denotes the most informative dref x such that John thinks Mary is in x, i.e., the same meaning as (102b).

(107)

Step 5: $[\![$(102a)$]\!]$ = $[\![$What$^{\nu}$ does John think? Where^{u} is Mary?$]\!]$

= $[\![$John thinks [Mary is where$^{u}]_{\nu}]\!]$ $\Leftrightarrow$

$\mathbf{M}_u[\![$John thinks [Mary is somewhere$^{u}]_{\nu}]\!]$ $\Leftrightarrow$

$$\lambda g.\left\{ g^{\substack{u\mapsto x\\ \nu\mapsto p}} \;\middle|\; \begin{array}{l} p = \cap p[\textsc{John-thinks}(p)], \\ x = \Sigma x[\textsc{location}(x) \wedge \textsc{John-thinks}(\lambda w.\textsc{At}_w(\text{Mary}, x))] \end{array} \right\}$$

$\mathbf{M}_u$

Step 4:
Applying the test in Step 3
to the result in Step 2

$[\![$John thinks [Mary is somewhere$^{u}]_{\nu}]\!]$ $\Leftrightarrow$

$[\![$John thinks $[\![\lambda w.$**Mary is somewhere**^{u} **in** $w]\!]_{\nu}]\!]$ $\Leftrightarrow$

$\lambda g.\{g^{\nu\mapsto p} | \; p = \cap p[\textsc{John-thinks}(p)]\}$ if $g^{u\mapsto x}$ such that

$\textsc{location}(x) \wedge g(\nu) \subseteq \lambda w.\textsc{At}_w(\text{Mary}, x)$

$$\Leftrightarrow \lambda g.\left\{ g^{\substack{u\mapsto x\\ \nu\mapsto p}} \;\middle|\; \begin{array}{l} \textsc{location}(x), \\ p = \cap p[\textsc{John-thinks}(p)], \\ \underbrace{p \subseteq \lambda w.\textsc{At}_w(\text{Mary}, x)}_{\text{i.e., } \textsc{John-thinks}(\lambda w.\textsc{At}_w(\text{Mary}, x))} \end{array} \right\}$$

Step 2:
selecting the maximally informative
proposition

$\mathbf{M}_{\nu}[\![$John thinks something$^{\nu}]\!]$ $\Leftrightarrow$

$\lambda g.\{g^{\nu\mapsto p} | \; p = \cap p[\textsc{John-thinks}(p)]\}$

$\mathbf{M}_{\nu}$

Step 1:
introducing a proposition dref

$[\![$John thinks something$^{\nu}]\!]$ $\Leftrightarrow$

$\lambda g.\{g^{\nu\mapsto p} | \; \textsc{John-thinks}(p)\}$

John thinks $\langle st, t\rangle$ — what$^{\nu}$ $\langle st\rangle$

Step 3:
A post-suppositional test
for the result of step 2 – $g(\nu)$,
with an introduction of a location dref

$[\![\lambda w.$**Mary is somewhere**^{u} **in** $w]\!]_{\nu}$ =

$\lambda m.\lambda g.m(g)$ if $g^{u\mapsto x}$ such that

$\textsc{location}(x) \wedge g(\nu) \subseteq \lambda w.\textsc{At}_w(\text{Mary}, x)$

$\lambda w.$ — Mary is where^{u} in w

As pointed out in Dayal (1994, 1996, 2000, 2016), both the derivation of direct dependency (see (104)) and indirect dependency (see (107)) should end with the same meaning. In particular, for indirect dependency like (102a), the two parts cannot be considered two independent *wh*-questions: 'The intonational contour that clubs the two questions together may be taken as a reflex of the syntactic adjunction of two CPs (Dayal 2016, p.40, footnote 12).'

The current analysis of question dependency is still in line with Karttunen (1977)'s 'true answer' view, not Hamblin (1973)'s 'possible answer' view (see related discussions in Section 6), because in no part of the derivation (see (104) and (107)) is *where*^{u} *Mary is* considered a *wh*-question, and the derivation never yields a Hamblin set for *where*^{u} *Mary is*. Under the current analysis (implemented with dynamics semantics), the derivation always starts with a non-determinate introduction of drefs, and it is the application of maximality / answerhood operators that truly fulfills the question meaning (i.e., L-analyticity) and generates its maximally informative analytical answer (see where $\mathbf{M}_u$ is applied in (104) and (107)). Eventually, the sentences in (102) address a single question and amount to '(it is) the place where John thinks Mary is at (that John thinks Mary is at).'

A relevant remark is that the presence of multiple *wh*-items does not always mean that the underlying QUD is about each of these *wh*-items. The analysis of the pair-list reading in Section 5.3 and the discussion of question dependency data suggest that their underlying QUD is only about one *wh*-item (see the underlined parts in (108)). The application of the maximality operator and the selection of the defintie dref for the other *wh*-item yield rather an intermediate product, not directly resulting in QUD resolution. This is not counter-intuitive: e.g., the sentence in (109) also does not mean that its QUD is about who came. After all, under the current proposal, a *wh*-item basically has the same meaning as definite determiner *the*, with an indefinite component (responsible for dref introduction) and a definite component (i.e., a maximality operator, which usually is not applied immediately at the DP level). A *wh*-item does not intrinsically mark a QUD.

(108) a. (i) What does John think? <u>Where</u> is Mary? **Indirect dep.** (=(102a))
(ii) <u>Where</u> does John think Mary is? **Direct dependency** (=(102b))
b. Which girl read <u>which</u> book? **Pair-list reading** (=(81b))
$\rightsquigarrow$ Which girls read books? <u>Which</u> book did each of them read?

(109) Kuromi knows who came. (= (87), see Section 5.4)

6 Comparison and discussion

Section 5 has shown how the proposed 'two-layered answerhood' view and the notion of the maximally informative analytical answers are empirically useful, providing a smooth account for many phenomena hotly discussed in the recent literature. This section further addresses theoretical implications and directions for future research.

I will start with a comparison with related works, showing what makes the current proposal innovative and advantageous (Section 6.1). Afterwards, Sections 6.2–6.4 discuss (i) the answer-issue duality, (ii) the interplay between focus and *wh*-questions, and (iii) how to extend the 'two-layered answerhood' view to *yes-no* questions.

6.1 Comparison with related works

6.1.1 Conceptual understanding of the notion of questions

> 'There are four ways of answering questions. Which four? There are questions that should be answered categorically. There are questions that should be answered with an analytical answer, defining or redefining the terms. There are questions that should be answered with a counter-question. There are questions that should be put aside.'
>
> (Pañha Sutta, translated from the Pali by Thanissaro Bhikkhu, copied from Krifka 2011, p.1742)

Krifka (2011)'s review article 'Questions' begins with the above citation, which seems to suggest that questions are classified according to how they are answered. From an observer's perspective, how a question is answered does hint on what the question is like. However, from the perspective of interlocutors who are present, understanding the meaning proper of a question should conceptually and empirically precede providing an answer to it, or more generally, instinctively or deliberately making a decision about how to react to it. In this sense, a question should have its own meaning, which is independent from answers or reactions, while there should also be something that connects the question and interlocutors' answers or reactions. In this paper, I have identified the maximally informative analytical answer as (i) the meaning proper of a question and (ii) the bridge between a question and its answers or reactions. Understanding a question and reacting to it hinges on getting this maximally informative analytical answer.

This notion of maximally informative analytical answer also responds to another comment in Krifka (2011), with regard to what makes a question a question:

> 'The various uses of unembedded or root questions can be reduced to one basic pragmatic function, namely, **expressing lack of information of a specified type**. We will see how the wide variety of question uses can be derived from this core meaning. Embedded questions, on the other hand, do not imply lack of information.' (Krifka 2011, p.1743, bold font is mine)

Krifka (2011) attributes this 'lack of information' to unspecificity: 'we can assume that the sentence radical of questions in general is a proposition that is partly unspecified. (p.1743)' But unspecificity cannot explain our different reactions to *Someone smiled* and *Who smiled?*, or the difference between *Kuromi knows someone smiled* and *Kuromi knows who smiled* (see the discussion on various kinds of exhaustive knowledge in Section 5.4).

According to Gajewski (2002/2016) and Abrusán (2014), L-analyticity / L-triviality leads to ungrammaticality (e.g., L-analytical sentence **there is the cat* vs. *the cat exists*; see Section 2.2). Thus, as for a question, what truly makes humans uncomfortable and eager to react in a certain way is more likely L-analyticity, not unspecificity. In other words, the L-analyticity of the meaning proper of a question, i.e., its maximally informative analytical answer, leads to this feeling of lack of information and the need for additional information. For root questions, providing a non-analytical answer that carries additional information solves sentence-level L-analyticity at the discourse level. For embedded questions, their embedding environment also provides information that solves local L-analyticity at the matrix-clause level.

L-analyticity, which makes interlocutors uneasy, also explains why sometimes we use a counter-question to answer a question or raise a question that somehow forces people to put aside (e.g., (110)): We intend to make them uncomfortable.

(110) Context: Someone asks me to get a coffee for them and clean their room.
Me: Who do you think you are? The use of a question for a **sarcastic** effect

6.1.2 Formal frameworks of question semantics

There are three major approaches in modeling question semantics: (i) question as a **function**, (ii) question as a **set of propositions**, (iii) question as a **partition of worlds** (see (111)). A related framework, **Inquisitive Semantics**, will be addressed in Section 6.2.

A major concern in all these approaches is that true, felicitous answers to a question vary from world to world, so question representations need to be intensional. With this element in common, the three major approaches differ with regard to motivations and conceptual understanding of questions.

(i) The '**question as a function**' view essentially considers a question a function from a domain (associated with the *wh*-item) to propositions, which, when applied to items in the domain, teases apart those that make the function return true from those that don't (see (111a); see e.g., Hausser and Zaefferer 1978, Hausser 1983, and see e.g., Krifka 2001, Xiang 2021b for recent development).

(ii) The '**question as a set of propositions**' is motivated by data of embedded questions (e.g., *Kuromi knows who smiled* and *Kuromi knows My Melody smiled* have the same meaning) and considers question meaning equivalent to its (true) propositional answers (see (111b); see e.g., Hamblin 1973, Karttunen 1977, and see H. Li 2019, 2021 for recent development within dynamic semantics).

(iii) The '**question as a partition of possible worlds**' partitions the possible worlds into equivalence classes, addressing for a certain world w, what kind of worlds are those in which a question is resolved in the same way as in this world w, i.e., the equivalence class of x (see (111c); see e.g., Groenendijk and Stokhof 1982, 1984, 1990a).

(111) **Three major approaches in modeling question semantics** (see Krifka 2011)

a. **Question as a function** (see the categorial approach in Section 4.4)

$$[\![\text{who smiled}]\!] = \lambda w. \underbrace{\lambda x \in \text{HUMAN}_w[\text{SMILED}_w(x)]}_{\text{a function from a domain of humans to propositions}}$$

b. **Question as a set of propositions**

$$[\![\text{who smiled}]\!] = \{\lambda w.\text{SMILED}_w(x) \mid x \in \text{HUMAN}\}$$ Set of propositions

$$[\![\text{who smiled}]\!] = \lambda p.\exists x[\text{HUMAN}_w(x) \wedge p_w \wedge p = \lambda w'.\text{SMILED}_{w'}(x)]$$

Set of true propositions at the world w

c. **Question as a partition of possible worlds**

$$[\![\text{who smiled}]\!] =$$
$$\lambda w.\lambda w'.[\lambda x.[\text{HUMAN}_w(x) \wedge \text{SMILED}_w(x)] = \lambda x.[\text{HUMAN}_{w'}(x) \wedge \text{SMILED}_{w'}(x)]]$$

By splitting the world-dependent part (e.g., an answer like *Maruko-chan* to a question like *who came*) from the world-independent, L-analytical part (i.e., the maximally informative analytical answer *the one(s) who came* to a question like *who came*), the current proposal abandons the view that question representations need to be intensional.

As pointed out by Krifka (2011), 'the information inherent in a question is partitioned into a description of the domain and a description of the values (p.1755).' The conceptual notion of the domain and the analytical layer of the values are both invariant from world to world (see L-triviality) and thus can be considered extensional. Krifka (2011) also points out that 'there are questions that do not come with existential import. (p.1755)' Indeed, under the current analysis, the meaning proper of a question amounts to the analytical layer in the answerhood, and this analytical layer only involves definiteness, but not world-dependent existence (see also Sections 4.2 and 5.2 and Coppock and Beaver 2015).

Although the meaning proper of a question and its analytical answer is now treated in an extensional way, the current proposal still keeps the major conceptual and empirical benefits of all these three approaches.

On the conceptual front, as a definite description, the maximally informative analytical answer is fundamentally predicative, which is in line with the 'question as a function' view. Then since now the meaning proper of a question is considered a definite description, the current proposal is also in line with the 'question as a set of propositions' view in having a uniform treatment for declarative and interrogative CP complements of *know*. The current proposal is similar to the 'question as a partition of possible worlds' in that both views seek to capture the equivalence among the possible worlds and group equivalent worlds together. It is just that in analyzing the meaning proper of a question, the current proposal focuses on the analytical answer and puts aside the additional meaning attached to this analytical core. With regard to this analytical core, all the worlds are equivalent and can be grouped together, leading to an extensional representation.

On the empirical front, with regard to unembedded and embedded *wh*-questions, the current proposal has an empirical coverage as large as these mainstream approaches. The analysis of alternative question should be largely the same, with adjustments for domains associated with *wh*-items. Section 6.4 will suggest how to extend the current two-layered answerhood to *yes-no* questions.

Compared with the existing approaches, the current proposal is more advantageous in a few ways.

First, with the notion of the world-independent, invariant analytical answer, extensional question representations are not only conceptually well-grounded, but technically much more convenient and simpler than intensional representations, greatly facilitating the investigations of various empirical phenomena (see e.g., Section 5.1 on *wh*-conditionals, Section 5.3 on multi-*wh*-questions, etc.) We no longer need to type-lift a question simply because things like GQ can be used as a short answer to attach additional information onto the analytical core (see Section 5.2).

Second, technical facilitation and the enhancement of conceptual understanding also shed new light on some empirical phenomena. For example, in analyzing *wh*-conditionals (see Section 5.1) and embedded questions like *Kuromi knows who came* (see Section 5.4), it turns out that the derivation of sentence meaning can be solely based on the analytical answers, and how to give a true and felicitous answer to *who came* in interpreting *Kuromi knows who came* is irrelevant.

Third, with extensional representations for questions, the current proposal captures some parallelisms among natural language phenomena that have largely been studied separately. For example, in (112), an embedded degree question, a concealed question based on the use of relational noun *height* (see Barker 2016), and a *than*-clause receive the same analysis under the current proposal (see Sections 4.6 and 5.4). Degree semantics, which addresses the semantics of gradable adjectives and phenomena like comparative sentences, usually adopts extensional semantic representations.[13] The shared meaning of these expressions in (112), i.e., the analytical answer to the degree question *how tall is Junhyuk*, reflects that we can make degree semantics and question semantics fully compatible between them.

(112) **The shared meaning of the underlined parts**: HEIGHT(Junhyuk)

a. Kuromi knows how tall Junhyuk is. (= (85a))

b. Kuromi knows the height of Junhyuk. (= (86a))

c. Brian is taller than Junhyuk is ~~tall~~. (= (85b))

Fourth, with the notion of informativeness-based maximality in generating the analytical answer, the current proposal also brings a more unified treatment for *wh*-questions raised on different domains (e.g., entities, scalar values like degrees or intervals). Specific application of maximality / answerhood operators is based on the same idea of maximizing informativeness. We never need to loop over possible answers in the domain of *wh*-items, which is impossible for domains of intervals (see e.g., (113)).

(113) Q: How tall is Junhyuk?

A: Between 5 feet 11 inches and 6 feet, probably closer to 6 feet.

[13] See Fleisher (2018, 2020), Zhang and Ling (2021) for the view that the meaning of a *than*-clause is related to its corresponding degree question (or the answer to this degree question).

The current two-layered perspective on answerhood and the notion of analytical answers should also be useful in analyzing more cross-linguistic phenomena. One final note here is that in many languages, the same words can be interpreted as indefinites or *wh*-items, depending on context and intonation, as illustrated in (114) (see, e.g., Haspelmath 1997; see e.g., Y-H A. Li 1992 on Mandarin Chinese data). Does this provide evidence for the view that *wh*-items should be considered indefinites (see e.g., Karttunen 1977), rather than definite descriptions (see the current proposal; see also Section 4.2)?

It is likely that in English, *wh*-items carry their own indefinite component as well as definite component (i.e., maximality / answerhood operator), while in languages like Chinese, *shén-me* only has an indefinite component, and the maximality /answerhood operator for generating the maximally informative answer comes from intonation. Thus presumably, for languages like Chinese, we still interpret a *wh*-question as its definite, maximally informative analytical answer. Detailed investigations along this line are left for future work (see Section 5.1 for some discussion on *wh*-conditionals in Chinese).

(114) a. A: tā yí-dìng chī-le <u>shén-me</u>.
3.SG definitely eat-ASP something/what
A: 'He definitely ate <u>something</u>.' Chinese *shén-me* as an indefinite

b. B: nà nǐ shuō-shuō, tā chī-le <u>shén-me</u>?
then 2.SG say-say 3.SG eat-ASP something/what
B: 'Then please tell me: <u>what</u> did he eat?' Chinese *shén-me* as a *wh*-item

6.2 Interpreting *wh*-clauses: answer-issue duality

Although I have shown that an answer-based perspective can explain many empirical phenomena related to unembedded and embedded ***wh*-questions**, there are ***wh*-clauses** that cannot be interpreted with this answer-based perspective.

(115) ***Know* vs. *be thinking about***

a. Kuromi knows who will come.
 (i) $\rightsquigarrow$ Kuromi knows the <u>answer</u> to the question *who will come*.
 (ii) $\not\rightsquigarrow$ Kuromi knows the <u>issue</u> *who will come*.

b. Kuromi is thinking about who will come.
 (i) $\not\rightsquigarrow$ Kuromi is thinking about the <u>answer</u> to the question *who will come*.
 (ii) $\rightsquigarrow$ Kuromi is thinking about the <u>issue</u> *who will come*.

As illustrated in (115), although both *know* and *be thinking about* can take a *wh*-clause as complement, their complement clauses are not interpreted in the same way. The *wh*-clause in (115a) is interpreted as a genuine question, or rather the analytical answer to this question *who will come*. In contrast, the *wh*-clause in (115b) is interpreted as an issue: i.e., Kuromi is not thinking about the answer (i.e., the one(s) who will come), but rather considering different **alternatives** raised by this issue, *who will come*.

(116) provides further evidence on the contrast between *know* and *be thinking about*. The CP complement of *know* can be either a declarative or an interrogative clause (see (116a)), but *be thinking about* is only compatible with an embedded *wh*-clause, but not so compatible with an embedded declarative sentence (see (116b)).

(116) a. (i) Kuromi knows who will come.
(ii) Kuromi knows that My Melody will come.
b. (i) Kuromi is thinking about who will come.
(ii)??Kuromi is thinking about that My Melody will come.

With regard to these data, the underlying intuition is that the CP complement of *know* only expresses one alternative (see (115a) and (116a)). Even when the complement clause of *know* is a *wh*-question, according to the proposal of the current paper, this *wh*-question means a single definite item, i.e., the maximally informative analytical answer. On the other hand, the CP complement of *be thinking about* needs to involve uncertainty, i.e., multiple alternatives that constitute an issue (see (115b) and (116b)). While a *wh*-clause can introduce multiple alternatives, an embedded declarative clause like the one in (116b) cannot.

Inquisitive Semantics (see e.g., Ciardelli et al. 2019 for a thorough review) has been developed to model the notions of **issues** and **alternatives**. Within Inquisitive Semantics,

(117) a. An *information state* s (of type $\langle st \rangle$) is a set of possible worlds, i.e., $s \subseteq W$.
b. An *issue* I (of type $\langle st, t \rangle$) is a non-empty, downward-closed set of information states.
c. The maximal elements of an issue I are called the *alternatives* in I. Alternatives are of type $\langle st \rangle$.
d. The set of alternatives in I is written as $\mathsf{alt}(I)$, which is of type $\langle st, t \rangle$.
e. The *informative content* of an issue is the union of its alternatives, i.e., $\mathsf{info}(I) = \bigcup\{\alpha \mid \alpha \in \mathsf{alt}(I)\}$, which is of type $\langle st \rangle$.

Thus a proposition ϕ is lifted from a set of possible worlds (of type $\langle st \rangle$) to a set of sets of possible worlds (of type $\langle st, t \rangle$). A proposition ϕ is (i) *inquisitive* iff $|\mathsf{alt}(\phi)| > 1$ (see 'A or B' in (118)) and (ii) *non-inquisitive* iff $|\mathsf{alt}(\phi)| = 1$ (see 'A', 'B', and 'not (A or B)' in (118)).

(118) **Illustrations of Inquisitive Semantics**: With only 4 worlds: w_1, w_2, w_3, w_4

$[\![A]\!]$ = **Power-set**$(\{w_3, w_4\})$, $[\![B]\!]$ = **Power-set**$(\{w_2, w_4\})$

a. $\mathsf{alt}([\![A]\!]) = \{\{w_3, w_4\}\}$ — $[\![A]\!]$: non-inquisitive

b. $\mathsf{alt}([\![B]\!]) = \{\{w_2, w_4\}\}$ — $[\![B]\!]$: non-inquisitive

c. $\mathsf{alt}([\![A \text{ or } B]\!]) = \{\{w_3, w_4\}, \{w_2, w_4\}\}$ — $[\![A \text{ or } B]\!]$: inquisitive

d. $\mathsf{alt}([\![\text{not } (A \text{ or } B)]\!]) = \{\{w_1\}\}$ — $[\![\text{not}(A \text{ or } B)]\!]$: non-inquisitive

Within the framework of Inquisitive Semantics, the compatibility between an attitude-reporting predicate and their CP complement (as illustrated in (116)) can be based on (non-)inquisitiveness. *Know* is compatible with a non-inquisitive CP (i.e., with a single alternative), while *be thinking about* is compatible with a potentially inquisitive CP (i.e., with potentially multiple alternatives).

Both the issue-based perspective (see Inquisitive Semantics) and the answer-based perspective (the current paper) achieve some degree of unity in analyzing *wh*-clauses and declarative clauses. Under the answer-based perspective, (matrix and embedded) *wh*-questions and declarative sentences are analyzed in the same way, resulting in a deterministic update with a definite item (see (119)). Under the issue-based perspective, non-question *wh*-clauses and disjunctive declarative clauses can both express the tracking, maintaining, and cancelling of inquisitiveness (see (120)).[14]

(119) **The answer-based perspective**: A deterministic update

a. Kuromi knows who will come. — *Wh*-clause: Question

b. Kuromi knows that My Melody or Cinnamoroll will come. — Declarative

(120) **The issue-based perspective**: Tracking each of the (multiple) alternatives

a. If My Melody or Kuromi comes, Cinnamoroll will be happy. — Declarative

(i) $\rightsquigarrow$ If My Melody comes, Cinnamoroll will be happy.

(ii) $\rightsquigarrow$ If Kuromi comes, Cinnamoroll will be happy.

b. Whoever comes, Cinnamoroll will be happy. — *Wh*-clause

$\rightsquigarrow$ If x comes, Cinnamoroll will be happy. (x: each item in the domain)

[14] See Ciardelli et al. (2018) for experimental evidence about how conditionals with disjunctive antecedents are interpreted: humans track each alternative, and inquisitiveness projects to the global level.

In this sense, the answer-based and issue-based perspectives are complementary in characterizing natural language phenomena. The answer-based perspective targets the first, analytical layer of the answerhood to a *wh*-clause, i.e., the phenomena of picking out a definite description from its domain.[15] The issue-based perspective targets rather the additional, world-dependent layer, i.e., the phenomena of tracking (and cancelling / merging) each alternative (i.e., similar to each equivalence class of worlds). Both kinds of phenomena involve different sentence types: declarative sentences or *wh*-clauses. Thus the canonical view of classifying attitude-reporting predicates according to their compatibility with sentence types is highly problematic. As already shown in (115), the *wh*-clauses embedded under *know* and *be thinking about* are semantically different: an answer vs. an issue. Thus we need to conduct more fine-grained investigations on attitude-reporting predicates in future work.[16] [17]

6.3 The interplay between focus and *wh*-questions

The current proposal also captures the parallelism among cumulative-reading sentences, *wh*-questions, and focus phenomena (see (121) – (124)).

(121) ⟦Exactly three^u boys saw exactly five$^\nu$ movies⟧ (=(20))

$$\Leftrightarrow \lambda g\,.\left\{ g^{u\mapsto x}_{\nu\mapsto y} \;\middle|\; \begin{array}{l} y = \Sigma y[\textsc{movie}(y) \wedge \textsc{saw}(x,y)] \\ x = \Sigma x[\textsc{boy}(x) \wedge \textsc{saw}(x,y)] \end{array} \right\}, \text{ if } |x| = 3 \wedge |y| = 5$$

(122) a. ⟦Who^u smiled⟧ (= (21))

$$\Leftrightarrow \lambda g\,.\{g^{u\mapsto x} \mid x = \Sigma x[\textsc{human}(x) \wedge \textsc{smiled}(x)]\}$$

b. ⟦[My Melody and Kuromi]$_u$ smiled⟧ (= (24))

$$\Leftrightarrow \lambda g\,.\{g^{u\mapsto x} \mid x = \Sigma x[\textsc{human}(x) \wedge \textsc{smiled}(x)]\}, \text{ if}$$

[15] Krifka (2011): 'the information inherent in a question is partitioned into a description of the domain and a description of the values (p.1755)'.

[16] Lee (2019) uses data of factivity alternation to argue for a similar view: for embedded declarative clauses, sometimes they denote a public fact, while sometimes they denote an individualized opinion.

[17] Can we unify the issue-based and answer-based perspectives on *wh*-clauses into the same framework? Recent development of Dynamic Inquisitive Semantics (Dotlačil and Roelofsen 2019, 2021, Roelofsen and Dotlačil 2023) aims to achieve this goal, rewiring Inquisitive Semantics for analyzing various question phenomena. The current proposal and Dynamic Inquisitive Semantics basically have the same empirical coverage. However, by adopting intensional representations for questions and taking into consideration world-dependent information, Dynamic Inquisitive Semantics loses many conceptual and empirical benefits the current proposal has (see Section 6.1). As I have shown, there are many question-related phenomena that only involve the analytical layer, but not the world-dependent layer. A detailed comparison between theories is left for another occasion.

$g(u) = \textbf{My-Melody} \oplus \textbf{Kuromi}$

(123) $[\![\text{Only}^u \text{ Cinnamoroll came}]\!]$
$\Leftrightarrow \lambda g \,.\, \{g^{u \mapsto x} \mid x = \Sigma x[\textsc{came}(x)]\}$, if $g(u) = \textbf{Cinnamoroll}$

(124) $[\![\text{Even}^u \text{ Cinnamoroll came}]\!]$
$\Leftrightarrow \lambda g \,.\, \{g^{u \mapsto x} \mid x = \text{the one that leads to the highest measurement along a scale}\}$,
if $g(u) = \textbf{Cinnamoroll}$
(e.g., along a scale of likelihood, or a contextually salient scale, see Greenberg 2018, Zhang 2022)

Essentially, focus particle like *only* and *even* behave like modified numerals and *wh*-items in (i) containing an indefinite component, which introduces a dref, and (ii) applying an informativeness-based maximality operator, leading to a deterministic update. Then what if a focus particle and a *wh*-item co-appear in the same sentence?

Cross-linguistically, the co-appearance of a focus particle and a *wh*-item results in **intervention effects** in many *wh*-in-situ languages (see e.g., Beck 2006, Kotek 2019; see the contrast between ungrammatical pattern '*only* > *wh*' vs. grammatical pattern '*wh* > *only*' in Chinese examples in (126)).

Under the current proposal, I predict that the derivation for a *wh*-question with a focus item (see (125) and (126)) should be largely similar to the pair-list reading of a multi-*wh*-question (see Section 5.3 and (127)) or a *how-many* question that results in a pseudo-cumulative reading sentence (see Sections 3.4 and 5.3 and (128)), involving a 'non-parallel scope-taking strategy' in applying the maximality operators brought by the *wh*-item and the focus item. Presumably, intervention effects should be due to some kind of update failure (e.g., triviality or contradiction in applying maximality operators). A detailed development along this line is left for future research (see also Zhang 2023b).

(125) Which book did only Cinnamoroll read? English (*wh*-movement language)
$\rightsquigarrow$ the maximal book-sum such that its each atom is only read by Cinnamoroll

(126) a. * <u>zhǐ-yǒu</u> [Mary]$_F$ dú-le <u>shén-me</u> shū?
<u>only</u> Mary read-PFV <u>what</u> book
Intended: 'What is the book-sum x s.t. only Mary read x?' **only* > *wh*

b. <u>shén-me</u> shū <u>zhǐ-yǒu</u> [Mary]$_F$ dú-le?
<u>what</u> book <u>only</u> Mary read-PFV
'What book(s) did Mary read?' Chinese (*wh*-in-situ language): *wh* > *only*

(127) Which^u [DIST girl read which^v book] (=(78))

(128) a. How many boys saw exactly 5 movies (between them)? (= (31)/(70))
b. Exactly 3 boys saw exactly 5 movies (between them). **Pseudo-cumulative**

6.4 Two kinds of analytical answers to a *yes-no* questions

The 'two-layered' answerhood as well as the notion of analytical answer should also work for *yes-no* questions. What can be the analytical answer to a *yes-no* question?
Cross-linguistic data suggest that there are at least two kinds of analytical answers.

In English, as illustrated in (129), both positive and negative *yes-no* questions can be answered by a short answer that provides world-dependent information to the truth value of a proposition: *yes* correlates with a positive propositional answer (see (129a) and (129c)), while *no* correlates with a negative propositional answer (see (129b) and (129d)). Thus one kind of analytical answer to a *yes-no* question is its **truth value**.

(129) **Analytical answer to a *yes-no* question in English: its truth value**
a. Q: Did Kuromi come? A: Yes, she did. TRUTH(p) = 1
b. Q: Did Kuromi come? A: No, she didn't. TRUTH(p) = 0
c. Q: Didn't Kuromi come? A: Yes, she did. #No, she did. TRUTH(p) = 1
d. Q: Didn't Kuromi come? A: No, she didn't. #Yes, she didn't. TRUTH(p) = 0

In Chinese, as illustrated in (130), short answer *shì-de* indicates the agreement with the (positive or negative) question radical of a *yes-no* question (see (130a) and (130b)), while the answer *bù* indicates the disagreement with the (positive or negative) question radical of a *yes-no* question (see (130c) and (130d)).[18] In other words, in Chinese, *yes-no* questions are not answered with the polarity information of a proposition, but rather how the listener agrees with the speaker. Thus the **(dis)agreement of the listener** should be another kind of analytical answer to a *yes-no* question.

(130) **Analytical answer to a *yes-no* question in Chinese: (dis)agreement**
a. Q: kùluòmǐ lái-le ma? A: shì-de, tā lái-le.
Kuromi come-ASP SFP THIS 3.SG come-ASP
'Q: Has Kuromi come? A: That's right. She has come.' AGREE(u) = 1

[18] In Ancient Chinese, the morpheme *shì* (see (130a) and (130b)) was actually a demonstrative or pronoun, meaning *this*. It is likely that this meaning forms the basis for its current use: i.e., indicating agreement.

b. Q: kùluòmǐ méi lái ma? A: shì-de, tā méi lái.
Kuromi NEG come SFP THIS 3.SG NEG come
'Q: Hasn't Kuromi come? A: That's right. She hasn't come.' AGREE(u) = 1

c. Q: kùluòmǐ lái-le ma? A: bù, tā méi lái.
Kuromi come-ASP SFP NEG 3.SG NEG come
'Q: Has Kuromi come? A: That's wrong. She hasn't come.' AGREE(u) = 0

d. Q: kùluòmǐ méi lái ma? A: bù, tā lái-le.
Kuromi NEG come SFP NEG 3.SG come-ASP
'Q: Hasn't Kuromi come? A: That's wrong. She has come.' AGREE(u) = 0

These basic diagnoses about what constitutes the analytical answer to a *yes-no* question pave the ground for future studies, and in particular, for modeling interlocutors' expectation, bias, and interaction. Again, in analyzing various kinds of *yes-no* questions, we can separate out the analytical core from world-dependent, additional information and adopt extensional representations for *yes-no* questions.

7 Conclusion

This paper explores a new perspective on the semantics of *wh*-questions and their answerhood. Inspired by the multi-layered semantics in the interpretation of cumulative-reading sentences (Krifka 1999, Brasoveanu 2013, Charlow 2014, 2017, Bumford 2017), I show that the semantics of '*wh*-question + good short answer' also involves several layers. The semantic contribution of *wh*-items includes (i) dref introduction and (ii) non-local, sentence-level, informativeness-based maximization (which results in the maximally informative analytical answer). Then a good short answer contributes additional information on this maximally informative analytical answer. Following the literature on cumulative-reading sentences, I implement the proposal in dynamic semantics and consider a good short answer a post-suppositional test.

Detailed parts of the current proposal reflect many influential ideas in the existing literature on question semantics: in particular, Comorovski (1996)'s observation on cross-sentential anaphora to *wh*-items, Karttunen (1977)'s view that a *wh*-question means its true answer(s), Dayal (1996)'s Maximal Informativity Presupposition for *wh*-questions, Jacobson (2016)'s view on the basic status of short answers, Hausser and Zaefferer (1978), Hausser (1983)'s categorial approach, Roberts (1996/2012)'s work on QUD, as well as Caponigro (2003, 2004), Nathan (2006), Barker (2016)'s observations on natural language phenomena parallel to *wh*-questions. The current proposal inherits and renews their insights with a 'two-layered answerhood' perspective on *wh*-questions.

By teasing apart (i) the analytical, invariant information and (ii) the additional, new information in answering a *wh*-question, we gain a better, more uniform conceptual understanding and a more convenient compositional formalism in studying various empirical phenomena about questions and answers.

The current work also suggests that L-analyticity (see Gajewski 2002/2016, Abrusán 2014) is likely the underlying driving force leading to question interpretation. Our intuitive reaction of providing an answer that adds additional information to the analytical layer in the answerhood is to resolve this L-analyticity at the discourse level.

Moreover, the discussion in this paper suggests that the interpretation of *wh*-clauses demonstrates answer-issue duality. Sometimes we understand a *wh*-clause as a question and are interested in its analytical answer and how to further react to it and provide additional information. The current paper is largely devoted to the development of this answer-based perspective on *wh*-clauses. On the other hand, sometimes we use a *wh*-clause to raise an issue and express uncertainty, and it is the tracking, maintaining, and cancelation of its world-dependent alternatives that matters, leading to an issue-based perspective. This answer-issue duality in formal semantics is reminiscent of the wave-particle duality in physics. I believe that being aware of this duality will further our understanding of related natural language phenomena.

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Conflict of interest

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