Maximality and modality in infinitival Wh-complements

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Abstract. Infinitival Wh-complements exhibit a modal interpretation, which arises despite there being no overt lexical modal. In the only comprehensive analysis of the modality, Bhatt (1999) argues that it should be attributed to a covert modal operator. The semantics of this operator is more specific than the typical Kratzerian one. This paper reexamines the original motivation underpinning Bhatt’s analysis of the covert modal, and argues that such facts can be accounted for if the interrogative component of infinitival Wh-complements is specified to denote only maximal answers – a solution that is needed more generally in the interpretation of questions. Thus, it is not necessary to imbue the covert modal with a more specific semantics, making it possible to more broadly unify modal Wh-questions and infinitival Wh-complements.

Keywords. Wh-questions; covert modality; mention-some; maximal answers; infinitival structures

1. Introduction. Infinitival Wh-complements, exemplified in (1), have been relatively understudied compared to their finite counterparts.

(1) a. James knows where to eat.
    b. Linda figured out how to build a coffee table.
    c. Amelia wondered when to leave.
    d. Marvin decided who/which linguist to hire.
    e. Angela told James how fast to drive.
    f. Mindy forgot how many dignitaries to invite.

One of the core characteristics of infinitival Wh-complements, as observed by Bhatt (1999), is that they come with a certain kind of modal interpretation, even though there is no overt modal in the structure. For instance, (1a) seems to closely correlate with the meaning of the sentence in (2).

(2) James knows where he can eat.

Notably, James in both (1a) and (2) knows something about where it is possible to eat. Although Bhatt (1999) observes that the modal force interpretation of infinitival Wh complements can also have a necessity reading, we will leave this fact to Section 4.3.

The modal interpretation is one of the fundamental challenges in understanding the interpretation of infinitival Wh-complements: what is its source and compositional nature? In the most comprehensive investigation of infinitival Wh-complements to date, Bhatt (1999) argues

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that the modal interpretation arises from a covert modal operator, modeled within the Kratzerian framework for modality (Kratzer 1981; Kratzer 1991). Based on the observation that the modal of infinitival Wh-complements is always goal-oriented, Bhatt proposes that the ordering source consists of the relevant agent’s goals.

Bhatt (1999) assumes that infinitival Wh-complements are a type of Wh-interrogative and adopts the Hamblin-Karttunen framework for interrogative interpretation, wherein infinitival Wh-complements denote a set of propositions that represent the interrogative’s possible answers (Hamblin 1973), and in certain cases the denotation involves the set of true answers derived from the set of possible answers (Karttunen 1977). For both infinitival and finite modal Wh-complements, possible answers can be understood as modalized propositions, obtained by plugging in the right kind of entity, location, or time for the Wh-element. On the goal-oriented construal of the modal, the modal’s prejacent will be interpreted as ways of achieving the goal of the agent, according to the pragmatic approach in Condoravdi & Lauer (2016).

The main issue I address here is how we should formalize the following components of infinitival Wh-complements: the prejacent of the modal, the modal, and the nature of the answers. Like Bhatt, my focus is on infinitival Wh-complements that are embedded by the verb know. When embedded by know, Wh-complements must be pruned down from the set of possible answers to the set of true answers (Karttunen 1977; Heim 1994; Beck & Rullmann 1999).

Hintikka (1976) observed that infinitival Wh-complements have a Mention-Some interpretation, wherein, for example, the agent of know need only know some true answer, not the entire set of true answers. Assuming that the ANS operator selects true answers from the set of possible answers denoted by Wh-complements embedded under know, as proposed in Heim 1994, the Mention-Some interpretation of infinitival Wh-complements could be viewed as arising from existential quantification over the new set given by ANS. Although infinitival Wh-complements need not denote all true answers, Bhatt (1999) makes the crucial observation that they must denote at least one complete answer. The question that arises is: how can it be ensured that only complete answers make it into the set of true answers returned by ANS?

Complete answers in infinitival Wh-complements are those in which the prejacent of the modal constitutes an actual way of achieving the agent’s goal in w, which may involve a single step or multiple steps. In multi-step contexts, a complete answer may be one in which a plural entity supplies the value of who, or it may be a conjunction of two or more true answers. In either case, if ANS is simply a collection of all true answers consisting of complete true answers and their entailed answers, then existential quantification over that set, required for the Mention-Some interpretation, may return an answer that is true but is not complete. Entailed answers in these multi-step contexts are not complete, in that the prejacent of the modal is only a partial means of achieving the goal.

To address this issue, Bhatt proposes that infinitival Wh-complements have a special modal operator, one that is more specific than the Kratzerian one, which ensures that true answers will be complete answers—the modal’s prejacent will constitute an actual means of achieving the goal in w. In this paper, I argue for an alternative approach, where the ANS operator is fine-tuned to select only maximal answers, meaning these are answers that are not asymmetrically entailed by any other true answer. Maximal true answers will also be complete answers. This aligns with Fox’s (2013) approach to a similar issue in finite modal Wh-questions. On my proposal, the modal component of infinitival Wh-complements remains a standard Kratzerian modal.

The paper is structured as follows. In Section 2, I outline the set of interpretive facts that mo-
tivate Bhatt’s analysis of the covert modal. In Section 3, I show how the interrogative component of infinitival Wh-complements can account for such facts once it makes crucial reference to maximality of answers. In Section 4, I compare this kind of account with Bhatt’s account, showing that while the covert modal constitutes a solution to the problem demonstrated for infinitival Wh-complements, there is not independent evidence to support the existence of this covert modal, arguing in favor of the approach provided in Section 3.

2. *The problem.* The interpretive facts that motivate Bhatt’s (1999) analysis of the modality in infinitival Wh-complements arise, in part, from their association with a Mention-All reading. Before illustrating the problem, I present a framework that Bhatt adopts for interpreting embedded Wh-interrogatives, of which infinitival Wh-complements constitute a specific subtype. I then show how contexts in which multiple steps are required for achieving a particular goal pose a problem for this basic framework.

2.1. **The Mention-All Interpretation of Infinitival Wh-complements.** Following Hamblin (1973) and Karttunen (1977), Wh-interrogatives are understood to denote a set of propositions. When embedded by *know*, the set of propositions that the Wh-interrogative denotes should represent the set of true answers (Karttunen 1977, Beck & Rullmann 1999). Utilizing the basic function of Heim’s (1994) ANS operators, the set of true answers will be derived from the set of possible answers.

The Mention-All interpretation is generally considered the default for Wh-interrogatives, typically emerging in finite Wh-questions like those in example (3a). Under a predicate like *know*, the Mention-All interpretation of (3a) involves, at least, the weakly exhaustive set of true answers. For example, if the facts of a world *w* are such that Amy, Rex, and Val came to the party, then (3a) should be true if for every individual *x* who came to the party, Bill knows that *x* came to the party, as in (3b). If Bill only knows a subset of the true answers, as in (3c), then the conditions of the Mention-All interpretation are not satisfied.

(3) a. Bill knows who came to the party.
   b. Bill knows that Amy came to the party and that Rex came to the party and that Val came to the party.
   c. Bill knows that Amy came to the party and that Rex came to the party.

Mention-All interpretations arise in more restricted set of contexts, such as when the Wh-interrogative contains a modal (George 2011, Dayal 2016, Xiang 2016). In such cases, Bill may know only a subset of the true answers in *w*. For instance, even if it possible to get gas from three different locations in *w*: Shell, Exxon, and Chevron, it is sufficient for the truth of (4a) if among the true answers to the question, Bill only knows the proposition in (4b).

(4) a. Bill knows where we can get gas.
   b. Bill knows that we can get gas at Shell.

Hintikka (1976) first observed that infinitival Wh-complements give rise to a Mention-All interpretation. Assuming that the modality of infinitival Wh-complements arises from a goal-oriented covert modal operator (Bhatt 1999), then true answers are determined according to whether
the modal’s prejacent constitutes a way of achieving the goal in $w$. The shape of the answers to infinitival Wh-complements will include a controlled PRO, co-referent with the matrix subject, and it will include a modal operator modified by a goal $g$, which is some proposition that corresponds to the purpose clause (underlined in (5a)). For now, I use $\text{MODAL}$ as a placeholder for the actual modal operator of infinitival Wh-complements. If the facts of $w$ are such that calling Amy, Rex, or Val are all possible ways of achieving $g$, then the set of true answers to the infinitival Wh-complement in (5a) consists of the three propositions in (5b). Under a Mention-Some interpretation, if of the propositions in (5b), Bill only knows one, as specified in (5c), then this would be sufficient for the truth of (5a).

(5)  
\begin{enumerate}
  \item Bill knows who to call to get a job.
  \item True answers in $w$ to \textit{who to call to get a job}:
    \begin{enumerate}
      \item that Bill $\text{MODAL}^\text{job}$ call Amy,
      \item that Bill $\text{MODAL}^\text{job}$ call Rex,
      \item that Bill $\text{MODAL}^\text{job}$ call Val
    \end{enumerate}
  \item Bill$_i$ knows that he$_i$ $\text{MODAL}^\text{job}$ call Amy.
\end{enumerate}

The possibility of Mention-All and Mention-Some interpretations is presently a challenge for a unified theory of interrogative interpretation that aims at treating such interpretations as arising from the same basic components (see e.g., George 2011 for discussion). I will assume, along with many others (e.g., Beck & Rullmann 1999; George 2011), that the Mention-Some interpretation is semantically encoded as distinct from Mention-All interpretations.

In the Hamblin-Karttunen framework for interrogative semantics, the $Q$ operator returns the set of all possible answers to the Wh-interrogative. In extensions of this framework, $\text{ANS}$, as in (6), derives the set of true answers in $w$ from $Q$ (Heim 1994; Dayal 1996). In the case of infinitival Wh-complements, or modal finite Wh-questions, we can assume that the Mention-Some interpretation arises from existential quantification over that set.

(6)  \[ \text{ANS}(Q, w) = \{ p \in Q \mid p(w) \} \]

(7)  \[ \exists p \in \text{ANS}(Q, w) \]

The truth conditions for infinitival Wh-complements embedded under $\textit{know}$, such as (5a), can then be specified as in (8). Note that $\text{know}_{\text{ms}}$ is the question-embedding $\textit{know}$ that yields a Mention-Some interpretation. There is also a $\textit{know}$ that embeds a $\textit{that}$-complement, $\text{know}_{\text{prop}}$. The $\text{know}_{\text{ms}}$ relation between some individual $x$ and the intension of $\text{ANS}$ is defined in terms of $\text{know}_{\text{prop}}$.

(8)  \[ [\text{Bill knows who to call to get a job}]^w = [\text{know}_{\text{ms}}]^w(\text{ANS}(Q, w))(x) \]
\[ = 1 \iff \exists p \in \text{ANS}(Q, w)[\text{know}_{\text{prop}}(w)(x, p)] \]

This correctly derives the truth of (5a) if Bill knows the embedded proposition in (5c) since it is among the true answers in $w$. 


2.2. Goals with Multiple Steps. The problem for this analysis of infinitival Wh-complements is that this basic semantics for the Mention-Some interpretation, as in (8), is too weak to account for all interpretations of infinitival Wh-complements, especially when there are multiple steps for goal satisfaction as Bhatt (1999: 138–140) observes.

Suppose that in w, there are two alternative ways for becoming popular. One way is by talking to both Sue and Bill. Sue has a beloved cookie recipe and Bill has a specific icing recipe that complement Sue’s cookies well. Learning the combination of these two recipes by talking to both Sue and Bill will lead to popularity for Helen. Another way is by talking to both Val and Rex. Val and Rex are on the board of an exclusive club, members of which become popular. Val and Rex must meet each individual who wishes to be a club member. For (9) to be true in w, Helen must know a proposition that corresponds to the conjunction of two true answers where the two individuals from either of these relevant groupings (i.e., Sue and Bill or Val and Rex) supply the value of who. Notably, Helen need not know all true answers in w, consistent with a Mention-Some interpretation.

The basic intuition that this system must capture is that the sentence in (9) should return true (T) if Helen knows either what is specified in (9a) or what is specified in (9b). On the other hand, (9) should return false (F) if Helen knows a proposition that corresponds to the conjunction of two answers that make reference to individuals who do not jointly lead to popularity as in (9c), or if she knows a partial answer, corresponding to one propositional conjunct of a true answer in w as in (9d); in such cases, Helen cannot be said to know who to talk to achieve her goal in w.

(9) Helen knows who to talk to at the party to become popular.
   a. T in w if Helen_i knows in w that she_i MODAL_popular talk to Sue and that she_i MODAL_popular talk to Bill.
   b. T in w if Helen_i knows in w that she_i MODAL_popular talk to Val and that she_i MODAL_popular talk to Rex.
   c. F in w if Helen_i knows in w that she_i MODAL_popular talk to Sue and that she_i MODAL_popular talk to Val.
   d. F in w if Helen_i knows in w that she_i MODAL_popular talk to Sue.

However, given the current set up, the above desiderata are not satisfied. This is because ANS is, at this point, simply a collection of all true answers to the infinitival Wh-complement, which includes answers that are entailed by other answers. The relevant question-embedding know, know_ms in (8), is verified by any proposition in ANS that the agent knows; thus, it is possible that (9) will be verified if the only answer that Helen knows is the embedded proposition in (9d), or any other proposition asymmetrically entailed by a true proposition in ANS.

Notably, given the same context for (9a), the same problem arises from finite Wh-complements with overt modals.

(10) Helen knows who she can talk to to become popular.

Intuitively, if Helen only knows a partial answer, as in the embedded proposition of (9d), where MODAL is replaced by a goal-oriented can, Helen does not in fact know a possible means of becoming popular in w.
Even if we are to assume that \( x \) in (8) may denote plural individuals, a necessary assumption in any case,\(^1\) the problem persists. To give the covert modal of infinitival Wh-complements a bit more structure, I’ll assume, following Bhatt 1999, that MODAL is a possibility modal operator (\( \Box \)), modeled within the Kratzerian framework (Kratzer 1981, Kratzer 1991): it has a modal base and an ordering source. As before, \( \Box \) of infinitival Wh-complements is relativized to a goal \( g \) (as specified by the purpose clause), which controls the ordering source (discussed further in Section 3). The problem is illustrated in (11), where \( Q \) represents (some of the) possible answers to the infinitival Wh-complement in (9), and where the underlined propositions are those which would be included in ANS.

\[
\text{(11) } Q: \{ \Box^g(talk-to(h,s+b)), \Box^g(talk-to(h,v+r)), \Box^g(talk-to(h,s+v)), \Box^g(talk-to(h,s+r)), \\
\Box^g(talk-to(h,b+v)), \Box^g(talk-to(h,b+r)), \Box^g(talk-to(h,s)), \Box^g(talk-to(h,b)), \Box^g(talk-to(h,v)), \\
\Box^g(talk-to(h,r)) \ldots \}
\]

True answers that consist of plural entities entail answers which include their atomic individuals (Dayal 1996), which means that the problem remains: (9) may be true in \( w \) when the only answer that Helen knows is a partial one, such as \( \Box^g(talk-to(h,s)) \). This problem arises, in part, because of the existential quantification over ANS, introduced as a way to account for the requisite Mention-Some interpretation of expressions with infinitival Wh-complements. If the interpretation were, instead, Mention-All, the agent would be required to know all true answers, and the problem of partial answers would not arise.

In the following section, I outline a revision to ANS which makes crucial reference to maximality; this analytical move has precedent, particularly in the domain of modal-containing Wh-questions generally. I will then discuss Bhatt’s (1999) analysis of the problem illustrated here in Section 4, which involves altering the modal interpretation, as opposed to the interrogative interpretation. In Section 4.2, I argue that the resulting semantics for the modal does not have independent motivation, arguing in favor of locating the solution to this problem in the interrogative semantics. In Section 4.3, I discuss other aspects of the modal interpretation in infinitival Wh-complements, and argue that such aspects do not support the specific modal semantics proposed in Bhatt 1999.

### 3. Maximality as a solution

In this section, I demonstrate that by specifying the ANS operator to exclusively select maximal answers, as proposed by Fox 2013 and subsequently adopted in other studies like Xiang (2015) and Hirsch & Schwarz (2020), we will be able to reconcile the Mention-Some interpretation with the requirement for completeness in answers, aligning with the intuition outlined in (9).

Fox’s (2013) ANS operator (\( \text{ANS}_F \)) returns a set of propositions from \( Q \) true in \( w \), only if those propositions are not asymmetrically entailed by any other true proposition in \( w \).

\[
\text{(12) } \text{ANS}_F(Q, w) = \{ p: w \in p \in Q \land \forall q[w \in q \in Q \rightarrow q \not\subset p] \}
\]

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\(^1\) Allowing \( x \) in (8) to range over plural entities is necessary to understand answers to questions with collective predicates (e.g., \( \text{met} \) and \( \text{gather} \)), which require a plurality in the answer, as do Wh-elements with plural morphology. For discussion, see Dayal 1996.
On this view, ANS consists only of maximal answers, answers that are not entailed by any other true answers. This means that existential quantification over this set, necessary for the Mention-Some interpretation we are trying to derive, will only have maximal answers available. Answers that are maximal will also be complete, in that they are actual ways of achieving an agent’s goal in $w$.

This reformulation of the ANS operator is motivated, in part, in Fox (2013) by Wh-questions with overt modals that have a Mention-Some interpretation, but whose answers also must be complete in $w$. An illustrative context for this issue with modal Wh-questions is provided in Hirsch & Schwarz (2020), and is completely analogous to the situation illustrated for infinitival Wh-complements in (9).

(13) Context: The task is to add two letters to a word-skeleton to make a word.
   Word-skeleton: $f \ldots m$
   Which letters could we add to make a word?

(14) $\text{ANS}_F((13))(w) = \{\Diamond \text{word}(\text{add}(o + a)), \Diamond \text{word}(\text{add}(i + l)) \ldots \}$

The context very clearly sets up a situation in which two letters must be returned, anything less would not be a sufficient answer to the question. The $\text{ANS}_F$ operator correctly picks out the true answers that are not entailed by any other answer, which consist of plural entities supplying the value of the Wh-element.

This kind of solution can be ported over to capture the intuition that when an agent stands in the $\text{know}_{ms}$ relation to an infinitival Wh-complement, the proposition that they know must be complete. Applying $\text{ANS}_F$ to the set returned by Q, provided the context set up in (9), will return only the maximal answers: talking to Sue and Bill and Val and Rex are ways of achieving Helen’s goal.

(15) a. Helen knows $[\text{ANS}_F[\text{Wh–inf} \ Q \ [\text{who to talk to at the party to become popular}]]]$
   
   b. $[\text{ANS}_F][[\text{Wh–inf}]](w) = \{\Diamond \text{popular}(\text{talk-to}(h, s + b)), \Diamond \text{popular}(\text{talk-to}(h, v + r))\}$

   c. $[\text{Helen knows who to talk to at the party to become popular}]^w = 1$ iff $\exists p \in \{\Diamond \text{popular}(\text{talk-to}(h,s+b)), \Diamond \text{popular}(\text{talk-to}(h,v+r))\}[\text{know}_{\text{prop}}(w)(h,p)]$

In order for (15) to be true, Helen will have to know one of the propositions in (15b). Consequently, this analysis accounts for the intuition that Helen must know a complete answer by appealing to $\text{ANS}_F$, an operator that only selects maximal answers from the set of possible answers.

In contrast to the analysis we will discuss in the next section, the analysis described here does not require us to make any special modifications to the basic Kratzerian possibility modal. The main contribution of the present discussion is to show that the solution for Mention-Some interpretations for finite modal Wh-questions can be extended to infinitival Wh-complements. While this discussion is based on a particular account of the Mention-Some interpretation, another account of the Mention-Some interpretation, so long as it also captures the completeness

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2 Regarding the Mention-Some interpretation, Xiang (2022) argues that the account in Fox 2013 is not properly constrained, overgenerating Mention-Some interpretations in non-modalized Wh-questions. Xiang makes a set of analytical moves to address this problem, while preserving maximality of answers, as proposed in Fox 2013.
intuition, should also be able to account for both infinitival Wh-complements and modal finite Wh-questions.


4.1. The Modal’s Sufficiency Condition. Bhatt (1999) proposes that the intuition that the answer to an infinitival Wh-complement must be complete arises from a sufficiency condition imposed on the covert modal operator. Bhatt analyzes the interpretation of the covert modal as existential, predicting possibility interpretations for the modality of infinitival Wh-complements. He also observes and provides an account for the fact that the interpretation gets strengthened to weak necessity in certain contexts, which I return to briefly in Section 4.3.

Bhatt’s covert modal, which I will designate as $\diamond +$, differs from the standard Kratzerian analysis of a goal-oriented possibility modal in that it includes a sufficiency condition underlined in (16) below.

$\diamond +_{f,o}(p) = \{ w \mid \exists v \in \text{OPT}(w, f, o_+) : v \in [p] \} \wedge \forall v \in C \cap [p] : v \in \text{OPT}(w, f, o_+),$ \[ \text{where } C \subseteq \cap f(w), \text{ and where for any } w, g \in o_+(w) \]

(16) Bhatt’s covert modal$^3$

(17) $\text{OPT}(w, f, o) = \{ u \in \cap f(w) \mid \neg \exists v \in \cap f(w) : v \prec_{o(w)} u \}$

The first piece of $\diamond +$ is the familiar Kratzerian piece, corresponding to goal-oriented possibility: there is a world in the best worlds (OPT) in which $p$ is true. The ordering source $o_+$ must include the propositional content of the purpose clause, $g$.$^4$ For a more complete formalization of how the purpose clause should operate on an ordering source of a modal with a teleological construal, see Condoravdi & Francez (2022). The second piece—the sufficiency condition—says that $p$ is sufficient for achieving $g$ in $w$: all worlds in which $p$ is true, and share the relevant facts of $w$, are worlds in which $g$ is also true, i.e., the agent’s goals are met.

In essence, only a prejacent $(p)$ which is sufficient for achieving $g$ in $w$ will verify $\diamond +$; strict entailments of $p$ will not verify $\diamond +$ if they are not sufficient, and thus will not be among the set of true answers.

(18) $\diamond +_{f,o}^{\text{popular}}(\text{talk-to}(h, v + r)) \rightarrow \diamond +_{f,o}^{\text{popular}}(\text{talk-to}(h, v))$

This move is necessary for Bhatt under the assumption that the interrogative component returns any true answer, with no reference to maximality, as was given in (6). By making the covert modal stronger, the interrogative interpretation need not make reference to maximality, since the modal itself will rule out the truth of incomplete answers.

In the next section, I will show that a sufficiency condition of this type in the interpretation of goal-oriented modality is not generally needed. If $\diamond +$ exists, its distribution would have to be confined only to interrogative contexts, making it special-purpose. We should thus prefer a solution which does not require this special-purpose solution, such as that proposed in Section 3.

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$^3$ This notation differs from that given in Bhatt 1999, and is recast here in more familiar terms, adapted from Condoravdi & Lauer’s 2016 notation for goal-oriented modality.

$^4$ This goes beyond Bhatt’s formalization of the covert modal, but is warranted by the goal-oriented nature of the modal interpretation of infinitival Wh-complements; under such an interpretation for the modal, the purpose clause may be explicit or implicit.
4.2. Sufficiency is Not Independently Motivated. Modals used in teleological contexts do not necessarily convey that $p$ is sufficient for achieving $g$ in $w$. Notice that can, construed teleologically, is used felicitously in (19), and does not imply that using tofu ($p$) is sufficient for baking a vegan cake ($g$), only that it is possibility, perhaps among other items that could be used as a substitute for egg. In this case, the modal presumably has the semantics of a more standard goal-oriented modal with no sufficiency condition ($\Diamond$).

(19) To bake a vegan cake, you can use tofu.

\[ \Diamond_{v_{f,0}}^{\text{vegan–cake}} (\text{you use tofu}) \]

A sufficiency condition imposed on the meaning of can would lead to the implication that using tofu is sufficient for achieving $g$, but clearly, all worlds in which you only use tofu are not worlds in which you bake a vegan cake, at least in those relevant worlds whose causal and factual makeup is similar to that of the actual world.

One could imagine that there are two types of can: one with a sufficiency condition as in (16), and one without; the one without the sufficiency condition would characterize the interpretation of (19). However, one would then expect that both interpretations for can should be freely available. As it happens, in the context of interrogatives, $\Diamond^+$ must be used—assuming, for the sake of this discussion, that ANS consists of both maximal and non-maximal answers (as in (6)). For (20a) to be true, the proposition that Mary knows must include a complete list of ingredients as in (20b)\(^5\); this would be guaranteed by $\Diamond^+$.\(^6\)

(20) a. Mary knows which ingredients she can use to bake a vegan cake.

b. Mary know that she $\Diamond^+_{f,10}^{\text{vegan–cake}}$ use tofu, all purpose flour, sugar, baking powder, baking soda, salt, canola oil, vanilla extract.

However, if also, can may be $\Diamond$ without sufficiency then (20a) may be verified if Mary only knows the embedded proposition in (21).

(21) Mary know that she $\Diamond_{f,10}^{\text{vegan–cake}}$ use tofu, vanilla extract.

Tofu and vanilla extract do not, by most definitions, constitute a vegan cake. Intuitively, (20a) should not be true if Mary only knows the embedded proposition in (21). A solution to this problem that centers on the semantics of the modal, rather than on the semantics of the interrogative, then it would have to stipulate that $\Diamond^+$ is always active in interrogative contexts with can. This makes a strong case in favor of locating the requirement for the completeness of $p$ in the interrogative semantics, rather than in the semantics of the modal.

That $p$ be sufficient for goal realization is an intuition that arises in the context of questions, which may be traced to the fact that questions seek resolution, and a partial answer, in these cases, does not resolve the question. Thus, it is preferable to locate the requirement for sufficiency of $p$ in the interrogative interpretation, for instance, via maximality, as proposed in (12).

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\(^5\) The plurality of which ingredients just requires that more than one ingredient be listed in the answer that Mary knows. That the list of ingredients would have to be complete has to come from something else, i.e., the maximality of answers, or the sufficiency condition.
Notably, analyses of goal-oriented modality more generally do not require the type of sufficiency condition proposed by Bhatt (1999) (see especially Lauer & Condoravdi 2014 and Condoravdi & Lauer 2017).

4.3. DISCUSSION AND OPEN QUESTIONS. I have argued that specifying ANS so that it only return maximal answers obviates the need for Bhatt’s (1999) sufficiency condition on the covert modal. But we should ask, at this point, whether removing the sufficiency condition from the modal of infinitival Wh-complements has any other ramifications for Bhatt’s analysis. I will detail here one potential ramification, particularly with respect to the issue of the variable force interpretation available for the modal of infinitival Wh-complements. I will suggest that it is a non-issue once we consider a broader range of facts in the domain of variable force modality.

As observed in Bhatt (1999), the modality of infinitival Wh-complements seems to vary in force between possibility, paraphrased here as could, and weak necessity, paraphrased as should. Bhatt provides an account of this variable force modality, arguing that both interpretations arise from a single semantic source. Additionally, Bhatt identifies a key factor influencing the shift between possibility and necessity interpretations: when the prejacent of the modal entails the content of g, the possibility interpretation for the modal is most natural.

(22) I know where to get gas (to get gas).\(^6\)
   \[= I \text{ know where } I (\checkmark \text{ could/}#\text{ should}) \text{ get gas.} \]

Assuming that where ranges over locations, the prejacent of the modal for each possible answer will have the following shape: I get gas from LOC\(_1\), I get gas from LOC\(_2\), etc.; each one of these entails that I get gas. However, if g involves multiple goals, restricting the set of locations that would satisfy the agent’s goals, as in (23), then should becomes most natural.

(23) I know where to get gas to maintain my ethical standards.
   \[= I \text{ know where } I (#\text{ could/}\checkmark \text{ should}) \text{ get gas.} \]

In this case, all possibilities for p will not entail g since any and all locations from which it is possible to get gas may not be locations which would satisfy the conditions imposed by g.

Bhatt (1999) discusses two ways in which the sufficiency condition might interact with the variable force modality: (i) the sufficiency condition can be trivially satisfied, and (ii) that the modal’s prejacent p should be the only way achieving g in a context (C), a parameter referenced in the sufficiency condition (see (16)). The sufficiency condition is trivially satisfied in cases like (22), since p entails g. When the sufficiency condition is trivially satisfied, the modal reduces to a plain possibility modal, favoring the could paraphrase. However, whether p is trivially satisfied or not is not enough to capture the variable force on its own. Bhatt (1999: 153-154) also introduces additional contextual restrictions on the C parameter of the sufficiency condition: there can only be a single means of achieving g in C, which derives the necessity interpretation. On its own, then, the sufficiency condition does not account for the variable force modality. An analysis, such as Bhatt’s, that makes use of existential quantification in the denotation of the covert modal will require additional contextual restrictions to obtain the necessity interpretation, as in (ii). Such restrictions need not be associated with the sufficiency condition; some other component of mean-

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\(^6\) The goal is in parentheses since it would most naturally be implicit in this case.
ing involved in the interpretation of infinitival Wh-complements could also introduce this restriction. Thus, the availability of the variable force modality in infinitival Wh-complements does not hinge on the presence of the sufficiency condition.

Another question to consider is whether the denotation of the covert modal in infinitival Wh-complements should involve existential quantification or not. If there is good reason to think that the denotation of the covert modal should involve the semantic components that give rise to necessity interpretations, then the particularities of Bhatt’s analysis, such as whether the sufficiency condition is trivially satisfied or not, are unlikely to be relevant to explicating the difference between (22) and (23). One reason to pursue a necessity-based account of the covert modal comes from Hackl & Nissenbaum (2012), who focus on covert modality found in infinitival relative clauses (e.g., ‘he found a book to read’). Hackl and Nissenbaum argue—on the basis of facts that only pertain to the modal of infinitival relatives clauses—that if both the possibility and necessity interpretation are to arise from the same modal operator, it should be one with universal quantification. Bhatt’s (1999) analysis of the modal in infinitival Wh-complements is intended to extend to the modal of infinitival relatives, and if this point of connection should be maintained, then following up on Hackl and Nissenbaum’s conclusion for infinitival relatives would be worth pursuing in the domain of infinitival Wh-complements; namely, that the covert modal fundamentally involves the conventionalized components of necessity modals, and that possibility interpretations such as (22) arise in some way from those components. How that can be accomplished is still an open question.

5. Conclusion. This paper examined the original motivation of Bhatt’s (1999) sufficiency condition on the covert modal of infinitival Wh-complements, which centered on the fact that in conjunction with the embedding predicate know, the agent denoted in the matrix clause must know some complete true answer. As it happens, this interpretive fact has been observed for Wh-questions with overt modals more broadly, and accounts of such facts have only considered a solution in which the interrogative semantics is modified, rather than the modal’s semantics. This is likely because the overt nature of the modal in such cases gives us no reason to suspect that it is anything different in Wh-questions. As a modest, but important step forward in unifying the nature of infinitival and modal Wh-questions, I have shown that updating the interrogative component so that the true answers are maximal (as proposed in Fox 2013) obviates the need for Bhatt’s sufficiency condition. While there are still unresolved questions regarding the exact nature of the modal component in infinitival Wh-complements, this discussion provides valuable insights, allowing us to more precisely identify potential properties now that the sufficiency condition is no longer a central focus.

References


