Relevance-Based Partition Semantics for Why-Questions

MSc Thesis (*Afstudeerscriptie*)

written by

Jonathan Shaheen
(born October 25th, 1983 in Fort Wayne, Indiana, USA)

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Date of the public defense:	**Members of the Thesis Committee:**
August 27, 2010	Prof Dr Jeroen Groenendijk
	Prof Dr Martin Stokhof
	Prof Dr Frank Veltman

INSTITUTE FOR LOGIC, LANGUAGE AND COMPUTATION

Abstract

This work argues that partition semantics can be extended to cover why-questions and their answers, and then develops such an extension. Building on Jeroen Groenendijk's Logic of Interrogation and incorporating a theory of why-questions initially put forward by Bas van Fraassen, it provides a unified notion of contextual answerhood for both why-questions and constituent questions. Non-constructive and constructive versions of the semantics are indicated, their meta-logical features are briefly explored, and two applications for the semantics are described.

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1 Mission Statement

Why-questions are often thought to be different than other wh-questions. Semantic theories of questions routinely exclude them as a matter of fact.[1] Sometimes theorists even claim that they cannot be treated in one standard framework or another as a matter of principle.[2] The source of this difference is supposed to be the difficulty of saying just what a full answer to a why-question is.[3] When why-questions are included, the treatment is sometimes limited, often without comment, to those that ask for causal stories or for a specification of events that qualify as causes, as if the appearance of 'because' in a response to a why-question guarantees that what follows must be causal in nature.[4] In other cases, the notion of answerhood that covers the 'normal' wh-questions as well as the limited class of causal why-questions is claimed to be disjunctive:

> In other words, *in ordinary usage the notion of answer is used in a logically different way when it is applied to why-questions from the way it applies to other kinds of questions.*[5]

This ought to be a position of last resort, and a condition of success for this thesis is inducing the recognition that better positions are available.

In part, the limitation to causal why-questions is a concession to the limitations of the logical machinery available to linguists and logicians: it opens the door to a formalization using quantification over events as if they were normal objects, which seems like a relatively acceptable path to a promising approach for at least a large class of why-questions. But the limitation is also part and parcel of a certain prejudice in the philosophy of science literature from the beginning of the 20th century. In that literature, 'explanation' typically means *scientific* explanation, and for something to be explanatory, it has to resemble scientific explanations in quite substantive respects.[6] The centrality of scientific explanations to accounts of explanation

[1] E.g., to the best of the author's knowledge, all work in partition semantics, including Groenendijk (1999).

[2] Such a claim, with respect to partition semantics, was advanced in response to a question during the 2009 ESSLLI course "Topics in the Semantics of Interrogative Clauses" as if it were standard and unobjectionable.

[3] Colwell (1996) goes so far as to claim that it is impossible for a why-question to be 'truly answered'.

[4] E.g., Ginzburg (1995), 34-35.

[5] Hintikka and Halonen (1995), 647. Emphasis theirs.

[6] Woodward (2009), §1 notes that recent literature typically treats genuinely scientific explanations on a par with the explanations of folk science, and identifies "the task of

has the effect of ruling out a priori the possibility of many kinds of non-causal explanations, e.g., purported religious explanations, certain kinds of folk psychological explanations, etc. So far as a naturalist theory of explanation goes, so good. But one hears the occasional philosopher wonder how religious accounts can explain anything, differing as much as they do from the paradigm cases of explanation. Worse, the naturalist's prejudice can infect the treatment of why-questions via a certain conception of explanation, dubbed 'the erotetic version of the epistemic conception' of explanation by Wesley Salmon, according to which an explanation is an answer to a why-question.[7] The semantic theory is thus held hostage to the naturalism. No natural language, of course, is the sole property of naturalists, nor are all uses of language naturalistically acceptable, "nor is semantics a device for establishing that everyone except the speaker and his friends is speaking nonsense."[8] In short, there is nothing about the meaning of 'why' that requires a causal response, nor any other sort of scientifically respectable, or even folk scientifically respectable, response.

The mission, then, is to provide a unified notion of what it is to be an answer—in contexts, as it turns out—that covers both why questions, scientific or not, and constituent questions expressed using the other wh-question words. A less polemic way of introducing the project is to say that it investigates how to scale up a partition semantics for questions to cover all sorts of why-questions, rather than starting with a special case particularly amenable to formalization and either assuming the possibility of, or simply forswearing, scaling things up.[9] The result includes a fully general framework for a semantics for why-questions, that can—but need not—be restricted to apply exclusively to causal or scientific why-questions.

2 Prologue to a Partition Semantics for Why-Semantics

This section discusses the partition semantics framework and its application to why-questions. The intent is introductory and systematic rather than historical.

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a theory of explanation to capture what is common to both scientific and at least some more ordinary forms of explanation."

[7] Salmon (1984).

[8] Tarski (1944), 345.

[9] In his recent Logic Tea talk, entitled "The limits of formal language models", Mathias Madsen advocated the latter sort of move with respect to the general project of scaling up formal models, on Heideggerian and (late-)Wittgensteinian grounds.

2.1 The Partition Semantics Approach

Work within the partition semantics framework builds on foundational insights of Hamblin (1958), where the following three basic postulates about questions are presented:[10]

(1) An answer to a question is a statement.[11]

(2) Knowing what counts as an answer is equivalent to knowing the question.[12]

(3) The possible answers to a question are an exhaustive set of mutually exclusive possibilities.[13]

Hamblin (1958)'s apt description of the view of questions that follows from these postulates serves as a good general statement of the theory developed in Groenendijk and Stokhof (1984) and subsequent works:

> A question is equivalent to a decomposition (or section, or division) of the possible universes. The set of possible universes is split up into a number of subsets, each subset representing an answer to the question, i.e. consisting of exactly those universes consistent with the answer.[14]

Or as Groenendijk (1999), the incarnation of partition semantics extended by the present thesis, puts it:

> The meaning of an interrogative corresponds to a *partition* of the set of possible worlds W. Hence, it also corresponds to an *equivalence relation* on W.[15]

Given the centrality of Groenendijk (1999) to the present project, the central definitions for the semantics of an interrogative $?\vec{x}\phi$, where ϕ is a predicate logical formula (containing all and only the free variables in $\vec{x}$, which is allowed to have length 0), are reconstructed in (4) and (5).[16]

(4) $[\![?\vec{x}\phi]\!]_{w,g} = \{v \in W : \forall \vec{e} \in D^n : [\![\phi]\!]_{v,g}[\vec{x}/\vec{e}] = [\![\phi]\!]_{w,g}[\vec{x}/\vec{e}]\}$.[17]

[10] See Groenendijk and Stokhof (1994), 21-28 for a discussion of these postulates.

[11] Hamblin (1958), 162.

[12] Ibid., 162.

[13] Ibid., 163.

[14] Ibid., 166. We may of course understand Hamblin's 'universes' to be possible worlds.

[15] Op. cit., 47.

[16] The condition on the free variables in ϕ is only implicit in Groenendijk (1999), but appears explicitly at Groenendijk and Stokhof (1994), 35, in a section to which the later work refers.

[17] Groenendijk (1999), 47.

(5) $[\![?\vec{x}\phi]\!]_g = \{[\![?\vec{x}\phi]\!]_{w,g} : w \in W\}$.[18]

(4) gives the extension of an interrogative $?\vec{x}\phi$ at a world w, and (5) gives the meaning, i.e., the intension, of the interrogative. Notice that the extension of an interrogative at a world w is the set of worlds that agree on the truth values of all sentences resulting from replacing the free variables in ϕ with the appropriate number of elements of the domain of quantification. Since $?\vec{x}\phi$ asks which objects satisfy ϕ, the extension of the interrogative at a world w is the set of possible worlds corresponding to the interrogative's true exhaustive answer at w. Where ϕ is of the form Px, for example, $[\![?xPx]\!]_{w,g}$ is the set of worlds where the predicate P has the same extension as in w. It is a consequence of the universal quantifier in (4) that the extensions correspond to exhaustive answers, and thus that the intension $[\![?x\phi]\!]_g$ defined in (5) corresponds to a partition of, and therefore also to an equivalence relation on, W.

The goal of Groenendijk (1999) is not to defend the exhaustive answers at the heart of partition semantics, but rather to incorporate Gricean pragmatic principles as the central features of a logical semantic framework. Indeed, Groenendijk (1999) defines answerhood in such a way that it does not require exhaustiveness.[19] But the semantics given for interrogatives is nevertheless a partition semantics. The next section justifies the attempt to account for why-questions within that framework.

2.2 Partition Semantics for Why-Questions

Three separate justifications are necessary. First, because the framework has been generalized in various ways, the decision to work with partition semantics rather than some fancier or more powerful generalization must be explained. Second, because the framework presupposes a certain account of the identity conditions of questions, that account must be defended. Third, because the scope of partition semantics is limited to a certain class of questions, the location of why-questions within that class must be motivated.

2.2.1 Generalization Declined

Two generalizations demand comment here. The first is a successor to partition semantics, called **inquisitive semantics**, that builds on a novel logic

[18] Reconstructed following Groenendijk and Stokhof (1994), 32-33.

[19] Essentially, answerhood is defined in terms of partial answers. Cf. Groenendijk and Stokhof (1994), 58-60.

to generalize the framework, incorporate Gricean pragmatic principles, and make predictions about acceptable answers to inquisitive utterances. The second, described in van Rooy (2003), is a refined semantics of questions that covers more ground than partition semantics, as well as going deeper in that it actually explains why partition semantics is appropriate where it is.

Inquisitive semantics is the current project of Groenendijk himself. This approach construes propositions as proposals to update the common ground with one of a set of one or more possibilities, which are themselves sets of possible worlds. The possibilities are alternatives in a relaxed sense compared to the alternatives of partition semantics, as the multiple possibilities in the semantic value of an inquisitive formula are allowed to overlap.[20] As far as the present study goes, no interesting differences emerge, so the more intuitive and better known framework is here preferred.

The refinement of van Rooy (2003) gives the semantic value of a question as a certain kind of underspecified meaning, a function from decision problems to determinate semantic values. The idea is that the decision problem that a querier is facing, i.e., a choice between a number of given actions, plays a role in determining what would qualify as an answer to his question. That role can amount to determining the appropriate level of specificity, or even going so far as to identify the appropriate **conceptual cover**.[21] The semantic value returned for a question, as van Rooy (2003) notes, partitions the context set just in case, for each world in the context set, there is an ideal action among the relevant choices.[22]

The semantics to be given is similar to van Rooy (2003)'s account of questions in some respects. Fully specified semantic meanings will be accorded to why-questions only in contexts. An underspecified meaning, a Kaplanian function from contexts to determinate semantic values, can therefore be recovered simply by abstracting over the contextual elements. But the semantics supplied to why-questions in this thesis is intended to show how a partition semantics for why-questions can be given, so the focus will be on the fully specified, contextually determined meanings. The features of context that fill in the otherwise underspecified meaning, however, do not primarily have to do with decision problems. Certainly one might ask why

[20]See Groenendijk and Roelofsen (2009) for an introductory piece.
[21]Aloni (2001) introduces and discusses conceptual covers
[22]Op. cit., 10.

something happened in order to be able to make it happen again, and in that case a decision problem contributes to the identification of possible answers in that an answer must indicate the means for achieving the desired repetition. In such cases, e.g., where the desired effect can be achieved in multiple ways, the semantic value predicted by a van Rooy (2003)-style account of why-questions would not be a partition. But the presupposition to be made in what follows is that at least a large class of why-questions are asked with the simple goal of finding out which belief to adopt from among a number of options that the querier could be induced to believe. Such a decision problem satisfies the condition under which the semantic values of questions are partitions on van Rooy (2003)'s account just in case the relevant beliefs are mutually exclusive. Section 2.2.3 effectively makes the argument that this is the case. But the introduction of decision problems does not constitute progress toward the identification of the partition that corresponds to a given why-question, because the identification of the decision problem itself amounts to specifying the acceptable answers to the question. That is, identifying the decision problem just is identifying the partition.

2.2.2 Identity Conditions Affirmed

The partition semantics approach has also come in for more direct criticism. The identity conditions of a question in the partition semantics framework are given by its exhaustively interpreted answers, respecting Hamblin (1958)'s third postulate. But Ginzburg (1995) takes there to be two sets of data that motivate a different choice of identity conditions for questions.

The first set of data relates to the kind of underspecification of meaning posited by van Rooy (2003)'s account. The data involves differential acceptability of responses to what appears to be the same question in different contexts, as in Ginzburg's examples reproduced as (6) and (7).[23]

(6) [Context: Jill about to step off a plane in Helsinki.]
Flight attendant: Do you know where you are?
Jill: Helsinki.
Flight attendant: Ah, ok. Jill knows where she is.

(7) [Context: Jill about to step out of a taxi in Helsinki]
Driver: Do you know where you are?
Jill: Helsinki.
Driver: Oh dear. Jill doesn't (really) know where she is.

[23] The examples are at Ginzburg (1995), 7.

As van Rooy (2003) suggests, the contextually given goals of conversational participants (henceforth CPs) play a role in determining appropriate responses. Ginzburg also highlights the role played by the belief/knowledge states of agents.

(8) [Querier asks the question at 11:10.] Q: How do I get from London to Oxford?
A: Take the 11:24 from Paddington.

The question in (8) has only been answered if the querier knows enough about London trains to put the instruction to use.[24] The moral Ginzburg draws from such examples is that the information that resolves (or answers) a question "is relative to (at least) a purpose or *goal* and a belief/knowledge state.[25]

In addition, Ginzburg takes a second set of data to provide evidence against the plausibility of presupposing the existence of an exhaustive answer to a question that is always appropriate.

(9) Q: Who has been attending these talks?
The director: (Provides list of names)
I asked the director who had been attending the talks. She didn't really tell me. All she did was recite a list of names, none of which meant much to me.[26]

Although the director, we may imagine, provides an exhaustive response in (9), the appropriate responses in the contexts Ginzburg imagines are rather given at a coarser grain than lists of individuals. Beyond this, (8) is representative of a large class of interrogatives with intuitive 'mention-some' readings: mentioning in sufficient detail any of a number of ways of getting from London to Oxford would constitute a full and appropriate response. The upshot of all this is that Ginzburg (1995), like van Rooy (2003), argues that contexts must be taken into account to identify the appropriate responses to the same bits of syntax.

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[24]Cf. the "conclusiveness condition" in Hintikka's semantics for questions, as presented at, e.g., Hintikka and Halonen (1995), 639.

[25]Ginzburg (1995), 6.

[26]Ibid., 9. Note that the director's response is only exhaustive if it is also made clear that the list of names is complete, i.e., that only people on the list have been attending the talks.

But it is clear, as Ginzburg (1995) admits, that this data is only telling if the different queriers are taken to be asking the same question in a semantic, and not just (surface) syntactic, sense.[27] To settle the issue, he appeals to an intuition about how agents would respond to discovering they were interested in different kinds of answers, ultimately denying that the identity conditions of questions are given by the sets of mutually exclusive exhaustive answers acceptable in response to contextually situated interrogatives. The claimed intuition is that, in cases like (6) and (7), the queriers would, upon discovering their disagreement, simply agree to disagree about what Jill knows.[28] Although politeness could lead them to say as much, it seems much more plausible that they would, if they bothered to discuss it, agree that they were really interested in different questions. The flight attendant wanted to know if Jill knew which city she was in, while the driver wanted to know if Jill knew, say, what part of Helsinki she was in. The intuition to which Ginzburg appeals, then, is just unacceptable. So the basic partition semantics approach, wherein questions are identified with the sets of their contextually permissible exhaustive answers, is here retained. It deserves mention, incidentally, that Groenendijk (1999) supplies *logical formulae* of his query language QL with semantic values, not bits of natural language, and the questions in (6) and (7) would not be represented with identical formulae of that language.[29]

But there is also a more principled objection to Ginzburg (1995)'s approach. For it presupposes that the class of potentially resolving informational items—the responses that could qualify as an answer in some context—are fixed in advance. It thus relies on the notion of an explanation complete in every detail, what Railton (1981) calls an **ideal explanatory text**.

> The intuition underlying the account can be described in terms of the following metaphor: an agent possesses a stack of snapshots, some complete, others possessing certain blurred features, all of which putatively pertain to a situation *s* which she is attempting to characterize. Posing a question involves associating

[27] Cf. op. cit., 11-12.

[28] Ginzburg actually pursues an example based on (9), but the intuition is equally objectionable in any case.

[29] QL lacks a mechanism for a Westerståhl (1984)-style representation of context sets, so the formulas would have to contain different predicates. Even with such a mechanism, the context sets themselves would have to differ, resulting in distinct logical formulae for the two questions.

> a (possibly) partially blurred snapshot σ with s. Responding involves finding a snapshot that fills in, in fine or coarse grain, the blurred features of σ and predicating that it actually depicts s. The question defined by associating σ with s... is *resolved* if the stack contains at a point accessible to the agent a genuine snapshot of s that fills in the blurred features of σ with a grain size appropriate to the agent's current purposes.[30]

This intuition, when it comes to why-questions, is philosophically contentious, and although Railton and many others might accept it, here it is to be rejected on philosophical grounds. Another lengthy quotation is in order:

> The description of some account as an explanation of a given fact or event is incomplete. It can only be an explanation with respect to a certain *relevance relation* and *contrast-class*. These are contextual factors, in that they are determined neither by the totality of accepted scientific theories, nor by the event or fact for which an explanation is requested. It is sometimes said that an Omniscient Being would have a complete explanation, whereas these contextual factors only bespeak our limitations due to which we can only grasp one part or aspect of the complete explanation at any given time. But this is a mistake. If the Omniscient Being has no specific interests (legal, medical, economic; or just an interest in optics or thermodynamics rather than chemistry) and does not abstract (so that he never thinks of Caesar's death *qua* multiple stabbing, or *qua* assassination), then no why-questions ever arise for him in any way at all—and he does not have any explanation in the sense that we have explanations. If he does have interests, and does abstract from individual peculiarities in his thinking about the world, then his why-questions are as essentially context-dependent as ours.[31]

This philosophical detour is relevant here exactly because it has consequences for how why-questions will be approached. An approach via a notion of complete but unknown explanations is unsatisfactory enough, if van Fraassen (1980) is right, in scientific contexts. But in a general theory of why-questions, where the 'explanations' with which they are answered could be scientific, or religious, or even astrological in nature, Ginzburg's non-constructive approach is surely to be rejected. For any why-question stated

[30] Ginzburg (1995), 18-19.
[31] van Fraassen (1980), 130.

in natural language, a host of pre-determined stacks of photos would be needed, with the unblurred photo in any given stack picturing the explanandum from a unique angle, some impossibly fantastic. Generality aside, the Kantian influence at work can be more openly displayed by borrowing some terminology from Allison (1983). The approach to the semantics of why-questions preferred here is constructive and *anthropocentric*; Ginzburg's non-constructive approach is therefore set aside in the remainder as unacceptably *theocentric*. In fact, two versions of the semantics for why-questions will be presented. According to the first, relatively non-constructive version, there are complete explanations of propositions at worlds, with an anthropocentric account of contextually complete explanations built on top of them. But according to the second, relatively more constructive version, wherein the philosophical view advanced here is really implemented, there are no explanations apart from contexts.

That said, it needs to be shown that partition semantics is appropriate for at least a large class of why-questions. That is, it needs to be argued that why-questions can receive 'mention-all' readings, that they can demand complete, exhaustive, mutually exclusive answers.

2.2.3 Partitions Defended

The argument to be given in this section appeals to some simple intuitions about the permissibility of particular kinds of responses to why-questions. A notion of contextual completeness for answers to why-questions is defended, and the possibility of exhaustive and mutually exclusive answers easily follows.

Some doubt whether there can be such a thing as a complete answer to a why-question can be given. At its most extreme, the doubt concerns whether why-question has a complete answer. Colwell (1996) makes much of the possibility of asking follow-up questions, as in (10).

(10) Q: Why did Robert leave his wife?
P: Because he decided he'd had enough.
Q: But why did he decide he'd had enough?[32]

It seems to me the most natural reaction to examples like (10) is to conclude that the querier is asking a new why-question, rather than rejecting the

[32]Colwell (1996), 2, shortened and slightly modified.

response as an incomplete answer. Q's second question is simply a different question, which requires a different answer. Further, it is clearly possible to reject an answer to a why-question as only partial, which implicates that something like a complete answer could be given.

(11) Q: Why did McCain lose the election?
A: Because he picked a crazy woman as his running mate.
B: No, that's only part of it. There was also Katrina, the economy, the war in Iraq...

This section will make much of the acceptability of B's response in (11) in arguing for the partition semantics approach to why-questions. But appeal can also be made to cases that are, from an explanatory point of view, much simpler, like (12).

(12) Teacher: We learned last week that, neglecting air resistance, the law governing the distance a projectile launched at initial angle θ with initial velocity v_0 will travel is given by $d = (v_0 \cos\theta)(\frac{2v_0 \sin\theta}{g})$. We also talked about a ball launched at an angle of 35° that traveled, after we corrected for significant figures, 154 m. Why did it travel 154 m?

The only right answer here must give the ball's initial velocity, which (assuming the velocity was given in whole numbers) can only have been 40 m/s, as the curious reader can check in (13).[33]

(13) $d = (40\text{ m/s} \cos 35°)(\frac{2 \cdot 40\text{ m/s} \sin\theta}{-9.8\text{ m/s}^2})$
$= (32.8\text{ m/s})(\frac{2 \cdot 22.9\text{m/s}}{9.8\text{ m/s}^2})$
$= (32.8\text{ m/s})(4.7\text{ 1/s})$
$= 154\text{ m}.$

Notice, however, how much of a context had to be provided to fix conditions for a correct and complete answer. The semantics presented here incorporates context as making a crucial contribution to the meaning of a why-question. The claim that answers to why-questions can be complete does not, therefore, approach the objectionable part of the view characterized by Ginzburg's metaphor. Before leaving the topic of completeness, note that answers to why-questions often begin with 'because'. Colwell (1996)'s

[33]The curious reader could also check http://zonalandeducation.com/mstm/physics/mechanics/curvedMotion/projectileMotion/generalSolution/generalSolution.html, whence it was assembled.

examples all miss the mark because they construe dialogues with ineliminable repetitions of 'because' as attempting to provide a single answer to a single question.

Mention-All and Mention-Some Readings for Why-Questions

Once it is acknowledged that why-questions have complete answers when situated in particular contexts, the next observation is that most (if not all) why-questions have readings that call for those complete answers. B's contribution to the dialogue in (11) is only acceptable if Q can be taken as having asked for, and A can be taken as having implicated that he gave, a contextually complete answer. That is, Q must have sought and A must have tried to provide an answer that is accurately read exhaustively. As Groenendijk and Stokhof (1994) emphasizes, this means that the answer must be read as coming with a clause that effectively says "and that's all."[34] Q's question, then, is given a **mention-all** reading. It is actually difficult, it seems, to get mention-some readings for why-questions, but they can be forced, as in (14).

(14) Why did the Civil War break out? Describe one cause.

Because the notion of completeness is so heavily contextualized, mention-some readings for why-questions are definitely the exception rather than the rule. It will henceforth be assumed that the why-questions of interest receive mention-all readings. Moreover, because such questions ask for complete, exhaustive answers, it follows that their answers are mutually exclusive. Thus ends the defense of the partition semantics approach.

3 Reworking van Fraassen (1980)'s Account

In order to give a partition semantics for why-questions, the real work of this thesis begins with van Fraassen (1980)'s pragmatic theory of scientific explanation, described in §3.1. The progress beyond that work takes two forms. First, formal apparatus have improved over the past three decades to allow for a better understanding and more rigorous formalization of some aspects of the account. The primary improvement we make in this respect concerns the attendant theory of contrast-classes, which is discussed in §3.2.

[34]Op. cit., 57. The concern here is with their 'strong' exhaustiveness, which partition theories require, rather than the 'weak' version.

Second, to provide a theory of why-questions that is both general and defensible, the various notions of relevance used by van Fraassen (1980) are modified. The notion of scientific relevance is generalized to a genre-relative notion, as described in §3.3.1. The notion of explanatory relevance is individualized such that van Fraassen (1980)'s contextual relevance relation R is derived from the relevance relations associated with individuals, as described in §§3.3.2-3.3.3.

3.1 van Fraassen (1980)'s Pragmatic Theory of Explanation

In this section, van Fraassen (1980)'s account of explanation is described. That account, which construes explanations as answers to why-questions, provides much insight into why-questions. This insight deserves to be integrated into a semantic theory in much the same way that Groenendijk (1999) integrates Gricean pragmatic insights. The account thus provides the basic theoretical view of explanation that, after the modifications to be described and motivated below, underlies the partition semantics for why-questions that this thesis presents.

According to van Fraassen (1980)'s account, a why-question Q can be identified with a triple $\langle P_k, X, R\rangle$, where P_k is the **topic** of the question; X, a set $\{P_1, \ldots, P_k, \ldots\}$ of propositions, is a **contrast-class**; and R is a **relevance relation**.[35] The question "Why is the shadow 10 feet long?", for example, has as topic the proposition expressed by "the shadow is 10 feet long". A useful way to think of a contrast-class, which will be put to good use below, is as the set of possible answers to a question answered by the topic. Thus the aforementioned question might have the set of answers to the question "How long is the shadow?" as contrast-class, viz., the set of those propositions expressed by "the shadow is 8 feet long", "the shadow is 9 feet long", "the shadow is 10 feet long", "the shadow is 11 feet long", etc. Alternatively it might have the set of answers to the question "What is 10 feet long?" as contrast-class, viz., the set of those propositions expressed by "the line is 10 feet long", "the shadow is 10 feet long", "the tape measure is 10 feet long", etc.[36] Non-topic members of the contrast-class will occasionally be referred to as **contrasts** below. Identification of the contrast-class is a contextual matter, as is the extension of the relevance relation R. Indeed, the importance of context to the identification of a question stands as *the*

[35] This and the next few paragraphs give definitions presented at op. cit., 143-146.

[36] In line with Hamblin's first postulate, answers are expressed by full sentences, not mere noun phrases.

central insight for the provision of a partition semantics for why-questions.

Given a question $Q = \langle P_k, X, R \rangle$, a proposition A is called **relevant to** Q if and only if A bears the relevance relation R to the couple $\langle P_k, X \rangle$. An answer to such a question takes the form $\ulcorner P_k$ in contrast to (the rest of) X because $A \urcorner$, or $\ulcorner$because $A\urcorner$ for short.[37] A proposition B qualifies as a **direct answer** to such a question if and only if "there is some proposition A such that A bears relation R to $\langle P_k, X \rangle$ and B is the proposition which is true exactly if (P_k; and for all $i \neq k$ *not* P_i; and A) is true."[38] To settle terminology, we note that van Fraassen (1980) calls A the **core** of answer B. For clarity, (15) presents examples of all of these technical notions using the previous paragraph's example.

(15) Why is the shadow 10 feet long?

a. **Topic**: P_k :='The shadow is 10 feet long.'
b. **Contrast-class**: X := {'The shadow is 8 feet long.','The shadow is 9 feet long.','The shadow is 10 feet long','The shadow is 11 feet long.',...}
c. **Relevance relation**: R := {⟨'The pole is 15 feet long.',$\langle P_k, X \rangle$⟩,...}
d. **Question**: $\ulcorner \langle P_k, X, R \rangle \urcorner$
e. **Direct answer**: $\ulcorner P_k$; and for all $i \neq k$ *not* P_i; and the pole is 15 feet long.$\urcorner$
f. **Core of answer**: 'The pole is 15 feet long.'
g. **Form of answer**: $\ulcorner$The shadow is 10 feet long in contrast to (the rest of) X because the pole is 15 long.$\urcorner$ or 'Because the pole is 15 feet long.'

In addition to identifying a question with the triple consisting of its topic, a contrast-class, and a relevance relation and providing a criterion for a proposition being a direct answer to a question, van Fraassen (1980) gives an account of the presuppositions of why-questions. These presuppositions are three. First, there is the obvious presupposition that its topic is true. Second, there is the contextually-determined presupposition that, among the members of the question's contrast-class, only the topic is true. Third is the contextually-determined presupposition that at least one of the propositions that bears the question's relevance relation to its topic and contrast-class is true. He dubs the first two of these presuppositions the **central presuppo-**

[37] To read the sentences enclosed in corner quotes ('$\ulcorner \ldots \urcorner$') simply instantiate the variables as you go.

[38] Op. cit., 144.

sition of the question. The third presupposition, that the question possibly has a direct answer, explains the fact that unanswerable why-questions are to be rejected.[39]

The identification of these three presuppositions distinguishes van Fraassen (1980)'s accounts from its competitors. The first presupposition is common to accounts of why-questions.[40] The second presupposition imposes a restriction on contrast-classes, which some subsequent theorists have questioned.[41] The third presupposition departs from other accounts in ways that have serious consequences for the view of answerhood adopted by those accounts. In the extreme, a failure to recognize this presupposition can lead to the denial that why-questions have answers in the same sense as other questions.[42]

A further notion treated by van Fraassen (1980) is that of a question arising or being in order in a context. Given the body of accepted background theory and factual information available in a context, K, we can say that the question Q **arises in the context** (or **is in order in the context**) if K implies the central presupposition of Q and does not imply the denial of any presupposition. In other words, we are licensed to ask $\ulcorner$Why P_k?$\urcorner$ just in case the central presupposition of the question holds and we do not know (or hold beliefs that entail) that the question has no direct answer.

Following van Fraassen (1980)'s treatment of answerhood, he turns to the evaluation of answers, of which process he identifies three aspects.[43] First, an answer is evaluated "as acceptable or as likely to be true."[44] Answers ruled out by the context K do not count as answers; but probability relative to K is a means of comparatively evaluating answers not ruled out by K. Second, as noted above, K must imply the question Q's topic and the negation of its contrasts in order for Q to arise. But evaluating an answer requires evaluating how much it "favors" the topic over its contrasts relative

[39]Explaining the possibility of rejecting why-questions is one of the tasks that van Fraassen sets for his account of explanation. See van Fraassen (1980), 111-112.

[40]Bromberger (1992), for example, calls it the propositional presupposition of a why-question.

[41]Cross (1991), 249-252 recommends revising the restriction in the course of extending van Fraassen (1980)'s basic account to cover how-questions.

[42]Thus Hintikka and Halonen (1995) denies that why-questions have such a presupposition and eventually proposes, in the passage quoted in §1, a disjunctive notion of answerhood to account for the resulting abnormality.

[43]Op. cit., 146-151.

[44]Ibid., 146.

to “that part of the background information which constitutes the general theory about these phenomena, plus other ‘auxiliary’ facts which are known but which do not imply the fact to be explained.”[45] This background information is to be a pragmatically constructed part $K(Q)$ of the context K.[46] The best answers in deterministic cases are such that $K(Q)$ together with the core of the answer implies the topic and the negation of the contrasts.[47] But in non-deterministic cases, the quality of an answer is a matter of how the addition of the core of an answer to $K(Q)$ redistributes probabilities. Quality increases as the minimum odds of the topic against its contrasts increase and the number of contrasts against which the topic bears those minimum odds decreases.[48]

For clarity, Figure 1 represents the simplest explanatory situation:

Nodes representing the relevant elements of $K(Q)$ appear on the left side of Figure 1: $T_1, \ldots, T_m$ represent the part of the background information that comes from “the general theory” about the relevant phenomena, and $F_1, \ldots, F_\ell$ represent auxiliary facts. Under the nodes for elements of $K(Q)$, A represents the core of some direct answer. On the right side of Figure 1, nodes for members of the contrast-class X, including the topic P_k, appear. Shaded nodes are true; unshaded nodes are false. Finally, the arrows represent a joint dependence relation: the truth-value of a node with arrows pointing to it depends on the truth-values of the nodes from which the arrows originate. So, in the context K depicted here, ⌜Because A⌝ answers ⌜Why P_k?⌝.

This completes the presentation of the definitions given by van Fraassen (1980). This pragmatic theory will be translated into a partition semantics for why-questions. But first some developments of the account are in order.

[45] Ibid., 147.

[46] Ibid., 147 says that “the selection of the part $K(Q)$ of K that is to be used in the further evaluation of [an answer] A, must be a further contextual factor”—but of course K is the context, so “contextual” here has been rendered as “pragmatic” to avoid confusion.

[47] Ibid., 147.

[48] Ibid., 148. van Fraassen subsequently introduces an ad hoc complication in the notion of favoring to account for Simpson’s Paradox, which does not concern us here. He also allows a relevant explanans to be ‘screened off’ from being an answer by a temporally later relevant explanans, which is a job assumed to be handled by contextual relevance relations below.

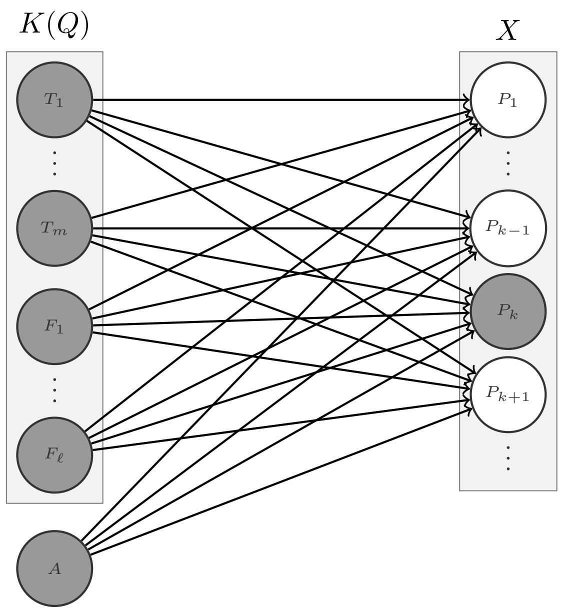

Figure 1: ⌜P_k because A⌝

3.2 Generating Contrast-Classes

According to van Fraassen, it is a presupposition of $Q = \langle P_k, X, R\rangle$'s arising in a context that all non-topic members of X are false. But while X is claimed to be contextually determined, the examples given seem to suggest that X is generated by purely syntactic mechanisms. In that case, the presence of a semantic constraint like falsity on non-topic members of X looks unmotivated. This section considers the syntactic mechanisms and the role of contrast-classes in the theory in order to understand that semantic constraint, and to see how the generation of contrast-classes is essentially contextual.

3.2.1 Truth-Value and Contrast

van Fraassen (1980) offers the examples in (16)-(18) to justify construing why-questions as contrastive.

(16) Why did Adam eat the apple?

a. Why was it Adam who ate the apple?
b. Why was it the apple Adam ate?

c. Why did Adam *eat* the apple?

(17) Why did the sample burn green (rather than some other color)?

(18) Why did the water and copper reach equilibrium temperature 22.5°C (rather than some other temperature)?[49]

van Fraassen regards these examples as offering reason to construe why-questions as generally having the form

(19) Why (is it the case that) P *in contrast to* (other members of) X?

where X is a contrast-class including P, rather than the simpler form

(20) Why (is it the case that) P?

as Sylvain Bromberger had earlier suggested.[50] Certainly the cleft construction and focus operators indicated by emphatic stress generate contrasts. In the cases of Adam's eating the apple, a chemical sample burning whatever color it did, and the water and copper reaching whatever equilibrium temperature it did, moreover, the contrasts generated all happen to be false. In the latter two cases, the contrasting colors and temperatures are even logically mutually exclusive with both the topic of the why-question and the other contrasts. But such mutual exclusivity appears to be an accidental feature of the examples chosen.

Examples (21)-(23) show that contrasts intuitively associated with a question are not generally mutually exclusive with a question's topic.

(21) Why did John go to the party?

a. Why was it John who went to the party?
b. Why was it the party that John went to?
c. Why was it attending the party that John did
d. Why did *John* go to the party?
e. Why did John go to *the party*?
f. Why did John *go to* the party?

(22) Why did combustion of the methane produce carbon dioxide (rather than some other gas)?

(23) Why did the water and copper (rather than the milk and iron) reach equilibrium temperature 22.5°C?

[49] Op. cit., 127. Spelling in (17) Americanized, as is usual in this thesis.
[50] Cf. Bromberger (1992), 157-165.

Clearly (21) could intuitively arise in a context even if others went to the party. The clefted readings in (21-a)-(21-c) do seem to suggest mutual exclusivity between topic and contextually salient contrasts. But the emphatic readings in (21-d)-(21-f) do not—surely others attended the party; John might have gone other places (if not at precisely the same time that he went to the party, still potentially within a contextually fixed time period of interest); and he might have performed other contextually salient actions (e.g., he might have *danced at* the party). (22) asks about the production of carbon dioxide of methane combustion, but need not be construed as only arising if the reaction produces no other gases. Indeed, methane combustion produces water vapor as well as carbon dioxide. (23) might arise in the context of an experiment intended to introduce students to the concept of specific heat in thermodynamics, even if the milk and iron reached the same equilibrium temperature.

Such observations led Cross (1991), citing examples like (24) and (25) uttered in contexts where all salient individuals drink too much, to suggest that the notion of contrast-classes be liberalized to allow in some cases for a contrast-class of true propositions.

(24) Why did *you* start drinking too much?

(25) Why does S drink too much?

But van Fraassen (1980)'s discussion of an answer favoring the topic against its contrasts in his account of the evaluation of answers to why-questions points to a difference between the intuitive notion of contrast suggested by examples like (16)-(18) and (21)-(25) and embraced by Cross (1991), on the one hand, and the notion of contrast underlying van Fraassen (1980)'s contrast-classes, on the other. The latter notion is that of contrasts that mutually exclude the topic, alternatives in a strong sense.[51] With an understanding of contrast-classes as contextually determined and mutually exclusive, (21)-(25) must be considered in context to discern the relevant contrast-classes. For example, in a situation in which little is known about S, the proposition that S drinks too much might have as a lone contrast that S does not drink too much; but in a situation where more is known, a

[51] The mechanism eventually endorsed here goes beyond contrasts that mutually exclude the topic: contrasts are alternatives in the very strong sense that they not only mutually exclude the topic, but also mutually exclude one another. The justification for taking this modeling decision, which relates to identifying constraints on relevance relations, is given below.

contrast might be, say, that S attends classes and completes assignments on time. But with this comment, it is clear that more needs to be said about the mechanism by which contrast-classes are fixed.

3.2.2 Contrast-Classes in Static and Dynamic Frameworks

In light of Cross (1991)'s attempted liberalization of contrast-classes, the syntactic mechanism of focus deserves scrutiny to see how it *could* generate sets of mutually exclusive alternatives as contrast-classes, as van Fraassen (1980)'s account of the evaluation of answers demands. The additional factors that demand attention, as van Fraassen (1980) consistently stresses, are contextual. In a static treatment, the necessary contextual factors can be introduced by reading all why-questions as focused in a fairly innocuous manner, although the details of the mechanism in this static approach remain opaque. Under this strategy, the canonical form of a why-question is

(26) Why (is it the case that) $[\mathrm{P}]_F$?

rather than (19) or (20). Such a canonical form incorporates the intuition that might lead one to claim all why-questions can be rewritten in clefted form without being obviously subject to the same objections.[52] Given the canonical form in (26), one of the standard approaches to the semantics of focus operators (Rooth (1985), Rooth (1992)) then predicts that contextual factors may play an essential role in selecting a set of mutually exclusive contrasts. According to that standard approach, a contrastive use of a focused phrase evokes a set of alternatives, which is "in some cases a pragmatically constructed object."[53] It is then possible and even plausible to argue that, in particular contexts, the pragmatic object that ought to be constructed is exactly the sort of contrast-class that van Fraassen needs. In a static framework, this is perhaps the best that can be done. But in a dynamic framework, context can provide contrast-classes without any need to construe why-questions as having the form in (26).

The key is to model context in a sufficiently sophisticated and slightly idealized way. The idealization is to require that P_k has actually been uttered before ⌜Why P_k?⌝ can be asked; but since the why-question presupposes that its topic is known, the idealization is slight. The bit of sophistication

[52](26) simply dodges the question of whether clefted rewritings are always possible, which Bromberger (1992), 160-161 denies.

[53]Rooth (1992), 86.

is then to represent **the question behind the utterance** of P_k as part of the context, in addition to the standard model of contexts as sets of possible worlds representing what is commonly known, and to use this question as the contrast-class for the why-question.

(27) Adam ate the apple.
  a. It was Adam who ate the apple.
  b. It was the apple Adam ate.
  c. Adam *ate* the apple.

(28) What happened?
  a. Who was it who ate the apple?
  b. What was it Adam ate?
  c. What did Adam do with the apple?

In an intuitive sense, (28-a) is the question behind the utterance (27-a), and similarly for (28-b) and (28-c) relative to (27-b) and (27-c), respectively.[54] So it is understandable that van Fraassen appealed to focus and clefting in his account of contrast-classes, since different clefted and focused rewritings of questions and assertions result in genuinely different questions, and therefore genuinely different contrast-classes.[55] Further, thanks to the slight idealization, P_k will always have been uttered, so the question behind the utterance will be available.[56]

The mechanism for the identification of contrast-classes will be a stack of questions defined slightly more broadly than questions behind utterances; it will be a stack of questions that have been answered in the course of the conversation, as this admits of a straightforward semantic characterization.[57] Within the partition semantics framework, including such a stack in the context provides a principled basis for drawing contrast-classes with the desired properties from contexts. That is, it supplies contrast-classes with mutually exclusive contrasts, with $\{\phi, \neg\phi\}$ is available in the limit case where the

[54] Cf. the use of the notion of *the question behind the utterance* in Balogh (2009).

[55] Something much emphasized by Mats Rooth's work on focus in Rooth (1985), Rooth (1992), etc.

[56] Alternatively, the idealization could be done away with if the notion of a question behind an utterance were extended to include an utterance of P_k in the course of uttering a why-question with P_k as its topic. But in fact an even stronger idealization is present in the formal game of §4 anyway, as shortly to be noted.

[57] Ginzburg (2009) advocated for the inclusion in context models of a similar feature, dubbed 'QNUD' for 'questions no longer under discussion', to account for the felicity of certain genre-specific conversational moves.

relevant question is a yes-no question, and more complex contrast-classes available otherwise.[58] The semantics supplied to these contrast-classes, of course, will be a partition semantics. Contrasts, then, not only mutually exclude the topic, but also mutually exclude one another. The justification for the latter feature is that it allows for a desirable constraint on the relevance relation, viz., that the selections the relevance relation makes vis-a-vis $\langle P_k, X\rangle$ should be reflected in the selections it makes vis-a-vis $\langle P_i, X\rangle$ for any other contrast. Parity among contrasts, in the sense that each mutually excludes all others, allows X to remain fixed in the interpretation of $\ulcorner$Why P_i?$\urcorner$ for each $P_i \in X$ in the appropriate counterfactual context, which facilitates the formulation of that constraint.

In the formal game presented in §4, the stack of answered questions in a given context is actually a subsequence of the sequence of moves made to reach that context. As such, the notion of questions behind assertions need not be explored further here. It is enough to note that the game always starts in an analogue of what Groenendijk (1999) calls "*the initial context* of ignorance and indifference" where the set of possible worlds representing the information present in the context includes all possible worlds and cannot tell any of them apart.[59] (In addition to not knowing any proposition ϕ, no issue about whether ϕ has been raised by a question for any ϕ.) From such a context, since what van Fraassen called the central presupposition of a why-question will be incorporated into the definition of licensing, and therefore pertinence, of why-questions in the game, ϕ must have been uttered before its explanation can be asked after, according to the rules of the game. But in the game, again via the definition of pertinence, a CP can only assert ϕ if it answers a question ψ?. The game, then, imposes a slightly stronger idealization than what seems necessary, for not only must something be asserted to introduce the question behind it, but the question itself must even be asked explicitly before the assertion can be made. Since this is the only way to introduce information in the game, even including such things as could be directly observed by CPs, context is effectively to be reconstructed as linguistic context.[60] One advantage of this idealization is that ψ? will then be in the stack of questions no longer under discussion, and therefore directly available in the context. In this way, its meaning according to partition semantics, $[\![\psi?]\!]_g := \{[\![\psi?]\!]_{w,g} | w \in W\}$, will be available

[58] There is thus no basis for the complaint at Markwick (1999), 196 that contrast-classes of the form $\{\phi, \neg\phi\}$ are "stretching the notion of a contrast."

[59] Op. cit., 48.

[60] Thanks to Jeroen Groenendijk for this perspicuous description of the idealization.

as a contrast-class for ϕ. It can serve as a contrast-class for the why-question exactly because ϕ is one of its answers and $[\![\psi?]\!]_g$ is a set of mutually exclusive alternatives. (The formal details will be presented systematically in §4.)

3.3 Revising Relevance

With this understanding of contrast-classes in hand, attention can be turned to the third element of a question according to van Fraassen (1980). Relevance makes two appearances in that theory of why-questions. Answerhood for why-questions is a matter of the contextual relevance relation R, but the extension of R itself is circumscribed by a non-contextual, objective relation of scientific relevance. The members of R are ordered pairs of a proposition (relevant responses) and an ordered pair of a topic and its contrast-class, where the propositions appearing as the first element of the ordered pairs in R must be scientifically relevant. This section adjusts this situation in two respects: first, it replaces the notion of scientific relevance with a generalized notion of genre relevance; second, it individualizes contextual relevance relations in order to provide an account of what they actually are, but in such a way that a contextual R can be recovered.

3.3.1 Generalizing Scientific Relevance

Since van Fraassen (1980) characterizes why-questions as part of an erotetic theory of explanation intended to compete against other views in the philosophy of science tradition, it is unsurprising that he restricts answers to scientifically relevant propositions.

> To sum up: no factor is explanatorily relevant unless it is scientifically relevant; and among scientifically relevant factors, context determines explanatorily relevant ones.[61]

In order to get a general theory of why-questions, the restriction must be done away with. Fortunately van Fraassen (1980) points the way to doing this in comments on the nature of scientific explanation:

> To ask that explanations be scientific is only to demand that they rely on scientific theories and experimentation, not on old wives' tales. Since any explanation of an individual event must

[61] van Fraassen (1980), 126. This and (parts of) the following quotations are also quoted in the footnote at Kitcher and Salmon (1987), 324.

> be an explanation of that event *qua* instance of a certain kind of event, nothing more can be asked.[62]

> To call an explanation scientific, is to say nothing about its form or the sort of information adduced, but only that the explanation draws on science to get this information (at least to some extent) and, more importantly, that the criteria of evaluation of how good an explanation it is, are being applied using a scientific theory.[63]

As these quotations indicate, why-questions asked in non-scientific contexts need not rely on scientific theories; scientific relevance only plays its circumscribing role in scientific contexts. Non-scientific contexts, then, should at least potentially admit contextual relevance relations that relate topic/contrast-class pairs with propositions that satisfy no objective criterion of scientific relevance. Nevertheless, explanation typically proceeds with reference to some background theory—scientific or otherwise.

> [Evaluation of how good an explanation an answer is] proceeds with reference to the part of science accepted as 'background theory' in [a given] context.[64]

To generalize the theory, then, we have to make room for the contextual nature of background theories.

In recent work on linguistic relevance, Jonathan Ginzburg has suggested that modeling conversational coherence sometimes requires appeal to discursive *genres*. Genres are individuated by, among other things, a set FACTS of propositions that each agent takes to be shared knowledge in the context.[65] Without getting into the details of Ginzburg (2009)'s type theoretical formalism TTR (type theory with records), we can take the contexts in which why-questions are asked to include a background theory, explicitly not requiring this background theory to be scientifically respectable. (But note that part of the idealization of the model is that CPs know nothing at the beginning of the game, and their ignorance extends to the background theory: its influence will rather be in the form of a constraint on what non-logical symbols can appear in utterances.) Astrological contexts

[62] Op. cit., 129-130
[63] Ibid., 155-156.
[64] Ibid., 141.
[65] Ginzburg (2009), 8.

are presumed to be as legitimate as scientific contexts when it comes to the conversational coherence of asking and answering why-questions. For example, the question 'Why did the Scorpio man part from the Taurus woman?' asks for an explanation of a break up as an explanation of the breakup *qua* instance of a breakup between Scorpio and Taurus. An answer that relies on astrological theories is therefore contextually appropriate, i.e., conversationally coherent, and its felicity (if not goodness per se) is to be evaluated relative to astrological theories. There may be, over and above this standard of coherence, some objective standard for explanations that relies more inflexibly on science, but that is an issue for metaphysics and not formal semantics. As van Fraassen (1980) says, "total immersion in the scientific world-picture... is proper to situations in which science is pursued or used"—though it isn't proper elsewhere.[66] Scientific relevance, then, is to be replaced by a genre-relative notion of relevance: what is important is only that the genre-relative notion of relevance constrains the contextual relevance relation and, although no account of the evaluation of answers to why-questions will be presented here, that such an account makes reference to the genre-relative background theories.

Only the most obviously logical feature of background theories provides a direct constraint in the present model: utterances must be in terms of the background theory. But many scientific theories put non-logical, more substantive constraints on what can count as explanatorily relevant. Special and general relativity, for instance, rule out events outside the past (neglecting time travel) light cone of an event from causing it. Nor is this the only such example. Psychological egoism, again a plausible "background theory" for a conversation in which why-questions are asked and answered, might be taken to require that explanations for intentional actions appeal to the agent's self-interested calculations. But these constraints are indirect, and might not even constrain answerhood to begin with.

(29) Imagine two philosophers, committed to both a neo-Humean theory of lawhood and general relativity, observing an event e. In their world, it may be supposed, e is governed by a fairly simple law L, and general relativity holds. But the philosophers are discussing a counterfactual world w', in which e is not governed by L because an event e', space-like separated from e, does not conform to L. The law governing e in world w' is then some other law L'. Then

[66] Op. cit., 92. van Fraassen explicitly excludes discussions of fiction from the proper domain of 'the scientific world-picture', but more is clearly justified.

a. Philosopher 1: Why e-governed-by-L'-in-w' (rather than e-governed-by-L-in-w')?
Philosopher 2: Because e'.

seems to be a permissible exchange.

Perhaps counterintuitively, the constraint of general relativity that denies e' a causal role in the explanation of e fails to prevent e' from appearing in an answer to a why-question about, i.e., in an explanation of, e. Since nothing semantic rules out sufficiently doctored contexts like the one in (29), such constraints should not be written into the account. Insofar as background theories contribute substantive, non-logical constraints, they affect only what relevance relations are admissible, the discussion of which is now due.

3.3.2 Individualized Explanatory Relevance

Essentially pragmatic features of context are to provide van Fraassen (1980)'s R. The essentially pragmatic features of context that provide R are those that relate to CPs: speakers and their audiences. It is facts about speakers and their audiences, then, that prevent van Fraassen (1980)'s theory of why-questions from being an "anything goes" theory, as charged by Kitcher and Salmon (1987). Rather, exactly those things go which go in some context. Kitcher and Salmon (1987) are right, however, that what the van Fraassen (1980) account lacks is a theory of relevance relations. A major part of the aim of the present thesis is to provide a framework within which such a theory can be developed, and to make some initial suggestions in that direction.

Since it is facts about speakers and their audiences that underlie the relevance relation R, a representation of the CPs must be an additional part of the context. So far, then, contexts will include a representation of the common ground, a representation of answered questions, a representation of a background theory, and a representation of the CPs. But van Fraassen (1980) says less than he could have about how to get from the sophisticated contexts, to which he so frequently appeals, to relevance relations themselves. An obvious way to add structure is to let individual CPs contribute to the contextual relevance relation R, rather than just positing R on top of the other elements of the context. For the purposes of providing a framework, going forward the idealization is adopted that the responses to why-questions that CPs would offer and accept vary with respect to these factors (to be supplemented in the actual formalization by a representation of all utterances in the dialogue, to facilitate representing the answered questions) and no others. CPs will be taken to come with **worldviews**, which demarcate the kinds of answers they would offer and accept in various contexts. Formally, worldviews will be associated with functions from contexts to individual relevance relations.

Three Logical Constraints on Individual Relevance Relations

Those individual relevance relations are subject to several constraints, some of a logical nature. First, individual relevance relations are supposed to encode the interests of a CP in approaching a why-question about the occurrence of one outcome among a set of contrasts. What is relevant to explaining the topic according to a certain set of interests should intuitively be closely tied to what would have been relevant to explaining one of its contrasts according to the same set of interests, if only that contrast had come true rather than the topic. So one constraint that ought to be satisfied by relevance relations, just in virtue of what they are supposed to be, is that, for each proposition related to the topic/contrast-class pair, and for each contrast in the contrast-class, there should be a proposition relevant to that contrast relative to the same contrast-class. A natural implementation of this constraint is to look for a question 'behind' an answer, in the same way that a contrast-class is fixed by the question behind the utterance of the topic, and require that different answers to this question are associated by individual relevance relations with different contrasts.

(30) If an individual relevance relation R_j relates ϕ_k to $\langle P_k, X\rangle$, then there is a question $?\vec{x}\psi$ and a distinct ϕ_i for each P_i such that $\{[\![\phi_i]\!]_g : i \text{ such that } \exists P_i \in X\} = [\![?\vec{x}\psi]\!]_g$ and R_j relates ϕ_i to $\langle P_i, X\rangle$.

This constraint on individual relevance relations incorporates what is right about the metaphor from Ginzburg (1995) that was criticized in §2.2.2.[67] Why-questions ask for a missing ("blurry") piece of information, and the acceptable answers to a why-question are the contextual alternatives for providing it (or for sharpening the resolution, so to speak).[68]

Second, since relevance ultimately ought to pick out complete explanations,

[67] It also incorporates the position of Schaffer (2005) that causation is contrastive on both the cause side and the effect side, although obviously in the more general framework of explanation.

[68] Cf. the transformation of why-questions into which-questions in Wisniewski (1999).

individual relevance relations should be subject to some kind of closure condition. The closure condition cannot be entailment itself, lest tautologies count as relevant.[69] Closing individual relevance relations under conjunction appears to be the best option available without developing the extra machinery necessary for a relevance logic.

(31) If an individual relevance relation R_j relates each of ϕ_1 and ϕ_2 to $\langle P, X \rangle$, then R_j also relates $\phi_1 \wedge \phi_2$ to $\langle P, X \rangle$.

In the formalization of §4, relevance relations will relate semantic values of formulae, rather than formulae themselves, to ordered pairs of the semantic value of a topic and the semantic value of the question behind it, but essentially the same condition will be placed on individual relevance relations.

Third, although the answers to a why-question that CPs would accept might change as new information is introduced in the course of the conversation, a condition is placed on individual relevance relations that effectively idealizes this sort of change out of the picture. Namely, once an individual's relevance relation picks out propositions that are relevant to a topic/contrast-class pair, exactly those propositions remain relevant, come what may.

(32) Once an individual's worldview picks out a relevance relation R_j that relates each of a (possibly singleton) set of formulae Ψ to $\langle P, X \rangle$ in the course of a game, then that worldview only picks out relevance relations that relate exactly those formulae to $\langle P, X \rangle$ for the rest of the game.

The formalization of this condition—which affects worldviews, the functions from contexts to individual relevance relations, rather than directly affecting individual relevance relations—will be simple enough once the contexts of the game are presented in §4.2.

Substantive Constraints and a Partial Armchair Taxonomy of Why-Questions

Apart from these logical constraints, the formalization will impose almost no constraints on what the R_i can be like. In part this is due to the possibility of conjuring up convoluted contexts like (29) to undermine apparent constraints from the background theory. But it is also due to the fact that

[69] Thanks are due to Frank Veltman here, especially for being kind in how he pointed this obvious fact out to me.

corpus studies are needed to develop a full taxonomy of why-questions, which must then be investigated with an eye to substantive constraints. Presently a partial taxonomy is offered, in order to see that some obvious options for forcing relevance relations to be well-behaved while maintaining generality run into trouble, but also to see what kinds of substantive constraints corpus studies might be able to uncover. The first three classes to be considered are distinguished by what motivates them; the rest are noteworthy because they undermine any fully general implementation of substantive constraints on why-questions.

First, there are why-questions asked with a specific decision problem in mind, such as how to make some observed phenomenon (not) occur again. In these cases, van Rooy (2003)'s strategy of using contextually salient decision problems to fill out underspecified meanings may be appropriate. For example, economists often ask (33-a) (with limited success) to try to avoid subsequent economic disasters.

(33) a. Why did the stock market crash in 1929?
b. Why did *Laverne & Shirley* get cancelled?

By way of contrast, Cartman on *South Park* is interested in (33-b) because he wants to make something similar happen again, viz., he wants to get *Family Guy* cancelled. (When he decides that getting a single episode pulled by censors will eventually do the trick, he pretends to be the son of a man killed by Islamic terrorists subsequent to the cartoon depiction of Muhammad in the *Jyllands-Posten*, and asks Fox executives to pull an upcoming episode of *Family Guy* that will depict Muhammad.) The upshot for the formalization of individual relevance relations is that, in such cases, what counts as relevant depends on what provides the information needed for the agent to resolve his decision problem.[70] But why-questions can also be asked out of idle curiosity, underlain by a decision problem no more narrow than deciding what to believe about the world. As argued in §2.2.1, the selection of the live options for alternative actions in the decision problem here just is the selection of explanatorily relevant answers.[71] So, while appropriate for

[70] Incidentally, this is the primary class of why-questions that might have plausible mention-some readings, e.g., for why-questions that ask about why something happened, where there were multiple distinct opportunities to intervene in the causal process.

[71] To reiterate one of the comments there, if the 'actions' in the decision problem are construed as adopting beliefs about contextually *complete* explanations, as was argued for in 2.2.3, then the partition semantics framework is appropriate for why-questions. Cf. van Rooy (2003), 10 (in the pagination of the version available on his webpage).

the noted class of why-questions, invoking decision problems cannot be a general strategy for constraining individual relevance relations.

Second, CPs can be motivated to ask why-questions by surprise, as Bromberger (1992) and Wisniewski (1999) require. In their cases, a default (what they call a "general rule") fails, confounding the expectations of a CP, who then seeks an explanation of its failure by finding a law approximated by the default (an "abnormic law" that "completes" a general rule), which actually governs what happened.

(34) A: Why is the plural of the French noun 'cheval' 'chevaux', that is, formed by dropping the last syllable and replacing it with 'aux' (rather than 'chevals', that is, formed by adding 's')?
B: Because it ends in 'al'.[72]

In (34), part of the complicated rule that actually governs pluralization in French is indicated, which explains why 'cheval' doesn't adhere to the default that French nouns are normally pluralized by adding 's'. Many why-questions ask in this way for an explanation of the failure of a default, and are answered by specifying some condition under which the default does not apply. Indeed, the *surprise* by which CPs are motivated is likely explained by their not having known that their general rule was merely a default, rather than a more universal truth. In that case, CPs actually need to revise their beliefs by concluding that the general rule is in fact merely a default, or else to replace the general rule by a more nuanced version 'completed' by an abnormic law. But this is only a special case of why-questions motivated by surprise at discovering that something previously believed cannot be true.

(35) Why is the temperature higher? I thought our measurements showed that the volume expanded enough to offset the increase in pressure.

In (35), an experimenter is presumably about to learn that his measurements or calculations were at fault, rather than that ideal gas law is merely a default.

Third, CPs, especially children, often ask why-questions because they lack enough knowledge to form expectations to begin with. Such questions can be taken to be motivated by curiosity rather than surprise.

(36) a. Child: Why do starlings fly?

[72] Adapted from Wisniewski (1999), 299.

Parent: Because starlings are birds.

b. Child: Why is the sky blue?
Parent: Because particles in the air are just the right size to reflect blue light so you can see it.

Acceptable answers to (36-a) might provide the child with the default he is missing; acceptable answers to (36-b) might provide part of a theory. (Note that the answer to the latter question is obviously partial, but there is still such a thing as the contextually complete answer, determined, among other things, by what the child is able and interested enough to understand.)

Fourth, many why-questions, particularly about why people act as they do, can receive rather arbitrary answers, because CPs can have arbitrary beliefs about the explanatory structure of the world.[73] For example, Cody Chesnutt apparently believes that he can do anything he wants because he looks good in leather. If he can induce the same belief in A by answering as in (37-a), then the exchange will be acceptable to the CPs.

(37) a. A: Why can you do anything you want?
Cody Chesnutt: Because I look good in leather.[74]

b. A: Why did John Smoltz do jumping jacks for nearly 30 minutes without stopping?
B: Because the Braves kept scoring.[75]

Understanding the other example in (37) requires knowing, as all American children do, that people involved in sports, and baseball players in particular, are ridiculously superstitious.

So far, why-questions do appear to behave systematically once beliefs in both straightforwardly truth-conditional propositions and defaults, as well as desires, are modeled in a sufficiently sophisticated way. In addition to modeling each CP, CPs would themselves have to maintain models of what their interlocutors believe, as they surely do. This much suffices to motivate the idea that individual relevance relations are indeed private, not public. But there are also why-questions that appear, from a semantic point of view,

[73] This cuts against Ginzburg (2009)'s project of internalizing a theory of conversational coherence within his semantic framework. If answerhood is not characterizable independently of CPs worldviews, then neither is conversational coherence, since answering a question is the epitome of a conversationally coherent move.

[74] Adapted from a popular song.

[75] Based on a true story (insofar as things on the Internet are sometimes true).

to be acceptably met with ad-hoc explanations, or even post-hoc rationalizations.

(38) Q: Why did you take the room key (rather than leaving it at the reception desk)?
A: Because I thought I'd be back before you.

Some exchanges fall outside the target phenomena here in that post-hoc rationalizations are plausibly excluded from the Gricean maxims governing cooperative information exchange around which Groenendijk (1999) built the game that this work extends. But even within exchanges covered by those maxims, the complicated why-questions of the social sciences, like (11), repeated here as (39-a), to say nothing of those of theology and the humanities, like (39-b) and (39-c), are also potentially problematic.

(39)
a. Why did McCain lose the election?
b. Why do bad things happen to good people?
c. Why is there something rather than nothing?

It is unclear, for these questions, that there are sufficiently well-articulated theories of the relevant phenomenon for the theories to contribute substantive constraints on why-questions. That said, it seems likely that sophisticated modeling of beliefs, including beliefs in defaults, should be sufficient to introduce constraints on relevance relations in a great majority of cases. But since corpus studies are needed to confirm this hypothesis, the present thesis contents itself with characterizing worldviews and individual relevance relations almost exclusively in terms of their purely logical features. The sole quasi-substantive constraint imposed is that relevance relations will be restricted to relating propositions that are meaningful by the lights of the background theory, which restriction will be implemented syntactically.

Now, which individual relevance relations within these weak constraints are actually instantiated by CPs in given contexts depends on how CPs actually are in those contexts: how they see the world; what they find enlightening; what they expect other CPs will find enlightening, etc. The further development of a theory of relevance relations would involve discovering the constraints that in fact govern the worldviews of actual CPs. The formalization of §4 merely aims to demonstrate that a partition semantics for why-questions is both possible and plausible, given a theory of individual relevance relations and worldviews. What is important is not the particular theory adopted, implausibly laissez-faire as it is, but the framework within which a theory of relevance fits into an extended partition semantics that can handle why-questions as well as constituent questions.

3.3.3 From Individual to Contextual Relevance

The picture can be completed if individuals' worldviews give rise to contextual, as well as individual, relevance relations. There are two obvious options for obtaining a contextual R from the individual relations: union and intersection. Each option has its advantages and disadvantages. Letting $R := \cup_i R_i$ would ensure that (40), a version of the logical constraint in (30), holds for R.[76]

(40) If a contextual relevance relation R relates ϕ_k to $\langle P_k, X\rangle$, then there is a question $?\vec{x}\psi$ and a distinct ϕ_i for each P_i such that $\{[\![\phi_i]\!]_g : i$ such that $\exists P_i \in X\} = [\![?\vec{x}\psi]\!]_g$ and R relates ϕ_i to $\langle P_i, X\rangle$.

For $R := \cap_i R_i$, (40) can fail if the individual R_i satisfy (30) via different questions $?\vec{x}\psi$. But the situation is reversed with respect to the logical constraint in (31), as the union of relevance relations, but not the intersection, may lead to new pairs of formulae related to some $\langle P_i, X\rangle$. It is easier to repair the defect for the union case, since a simple closure condition can be added, as in (41).

(41) To obtain a contextual R from individual relevance relations R_i by union, first take $R^* := \cup_i R_i$, and let $R \supseteq R^*$ be such that, if R^* relates ϕ_1 and ϕ_2 to $\langle P, X\rangle$, then R also relates $\phi_1 \wedge \phi_2$ to $\langle P, X\rangle$.

Nevertheless, the present thesis prefers $R := \cap_i R_i$ in order to interpret the formal semantic values 0 and 1 assigned to formulae. Given the role played by CPs' interests in determining those values, 1 and 0 cannot be interpreted as truth and falsity, respectively, but rather must be something more like intersubjective acceptability and intersubjective unacceptability, respectively. Since the individual relevance relations are supposed to represent anything that a CP would offer or accept as an answer, anything outside of the intersection of the individual relevance relations would be unacceptable to one or more CPs. Further, in a dysfunctional context involving individual relevance relations such that (40) is not satisfied by their intersection, it seems right to say that something less than ideal communication has actually taken place. While the CPs seem to agree about the answer to the why-question, they do

[76] Again, though for ease of exposition R is described here as if it has syntactic relata, in the formalization of §4, it has semantic relata.

so for different reasons; they are responding to different kinds of blurriness. On a similar note, while the mental states of CPs, including their models of each other, are private, the effect of any intersubjectively acceptable, i.e., contextually relevant, response to a why-question is public: the context will be updated with the proposition expressed in the usual way. The intension of a why-question, by way of contrast, will not be public, but CPs will have views as to what that intension is, based upon their individual relevance relations. And again, the case where these views diverge is non-ideal. Yet to object to this would be strange: the possibility of ideal communication requires explanation in terms of similarities between CPs. It should not just be written into a model.

A more straightforward advantage of the move is that it conceivably renders the partition semantics framework capable of handling certain types of open questions.[77] Why-questions can be open in the sense that they are put without a preconceived notion of what kind of answer they will receive. ((39-b) and (39-c) might be thought to provide good examples.) If the respondent has enough of a background theory in mind to know what the plausible answers look like, then her individual relevance relation will partition the context. All that is required for the contextual relevance relation to properly (i.e., non-trivially) partition the context is for the individual relevance relations of the other CPs not to rule out too much of what the respondent might like to say. The possibility of answers being circumscribed in this way means that, contra the pessimistic discussion of open questions in Groenendijk and Stokhof (1994), a sufficiently sophisticated version of the partition semantics framework might be able to handle many of them.[78]

4 The Extended Game of Interrogation

With the preliminaries of the previous two sections, it is now possible to supply a partition semantics for why-questions. As will become clear, this game extends the Game of Interrogation from Groenendijk (1999). Two options are provided, according to how seriously the anthropocentric constructivism about explanation alluded to in §2.2.2 is taken. The first option is presented gradually in §§4.1-4.6. The second option is then briefly presented in §4.7.

[77] Thanks to Anna Pilatova for encouraging me to think about open why-questions.
[78] Op. cit., 55-56.

4.1 The Game and Its Language

The definition of the extended game is given in (42).

(42) **The Extended Game of Interrogation** Interrogation is a game for two players: the **interrogator** and the **witness**. The rules of the game are as follows:

- The interrogator may only raise issues by asking the witness non-superfluous questions.
- The witness may only make credible non redundant statements which exclusively address issues raised by the interrogator.

As in Groenendijk (1999), logical notions, which ensure that the game is played according to Gricean maxims, will be formulated.

> The requirement that the witness makes credible statements is related to the Maxim of Quality; that the statements of the witness should be non-redundant, and the questions of the interrogator non-superfluous, relates to the Maxim of Quantity; and that the witness should exclusively address the issues raised by the interrogator is a formulation of the Maxim of Relation.[79]

The language of the game is built on top of the language QL from Groenendijk (1999), but formulating the conditions that determine whether a formula is well-formed requires a preliminary treatment of QL. QL itself is defined in (43).

(43) **Query Language** Let PL be a language of predicate logic. The Query Language QL is the smallest set such that:

a. If $\phi \in PL$, then $\phi \in QL$;

b. If $\phi \in PL$ with $n \geq 0$ free variables $x_1, \ldots, x_n$, written henceforth $\vec{x}$, then $?\vec{x}\phi \in QL$.

A preliminary semantics for the formulae of QL, essentially that of Groenendijk (1999), where it is motivated, appears in (44). In what follows, all first-order models are assumed to have a single domain D, following Groenendijk (1999). The possibility of lifting this assumption is addressed briefly at the end of §4.3.1 below. (Also following that work, though not to be discussed or especially used below: names are assumed to be rigid

[79] Groenendijk (1999), 45.

designators.[80])

(44) a. For $\phi \in PL$, $\mathcal{M}$ a first-order model, g an assignment function from variables x_i to a fixed domain D, $[\phi]_{\mathcal{M},g} =$
(i) 1 if $\mathcal{M} \models \phi[x_1/g(x_1), \ldots, x_n/g(x_n)]$;
(ii) 0 otherwise.
b. For ϕ, g as above, $[\phi]_g = \{\mathcal{M} : \mathcal{M}$ an f.o. model s.t. $[\phi]_{M,g} = 1\}$.
c. For $?\vec{x}\phi \in QL$, $\mathcal{M}, g$ as above, $[?\vec{x}\phi]_{\mathcal{M},g} =$
$\{\mathcal{N} : \mathcal{N}$ an f.o. model s.t. $\forall \vec{e} \in D^n([\phi]_{\mathcal{M},g[\vec{x}/\vec{e}]} = [\phi]_{\mathcal{N},g[\vec{x}/\vec{e}]})\}$
d. For $?\vec{x}\phi, g$ as above, $[?\vec{x}\phi]_g = \{[?\vec{x}\phi]_{\mathcal{M},g} : \mathcal{M}$ an f.o. model$\}$.

The meaning of a formula in PL is standardly given in (44-b) as the set of first-order models in which the formula is true. The extension of a formula $?\vec{x}\phi$ in $QL - PL$ evaluated at an f.o. model $\mathcal{M}$, given in (44-c), is the set of f.o. models that 'agree' with $\mathcal{M}$ about any substitution instance of ϕ. The meaning or intension of such a formula, given in (44-d), is the set of its extensions over all f.o. models.

This preliminary semantics allows us to formulate the constraints necessary to define the Extended Predicate Language of the Extended Game of Interrogation.

(45) **Extended Query Language** Let PL be a language of predicate logic and QL as in (43).
The Extended Propositional Language is the smallest set such that

- If $\phi \in PL$ is a sentence, $\phi \in EPL$;
- If $\phi, \psi \in PL$ are sentences, $\chi? \in QL$ such that $[\phi]_g \in [\chi?]_g$, then

  a. $\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi \in EPL$

  b. $\neg(\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi) \in EPL$; and
- If $\phi, \psi \in EPL$, $\phi \wedge \psi \in EPL$.

The Extended Query Language EQL is the smallest set such that:

- If $\phi \in QL$, then $\phi \in EQL$;
- If $\phi \in EPL$, then $\phi \in EQL$;

[80]Cf. op. cit., 46, especially the note on lifting the assumptions, and Aloni (2001) for arguments against variable domains (what she calls the 'Flexible Model strategy') and for the notion of conceptual covers, which can be exploited to lift the latter assumption.

- If $\phi \underset{\chi?}{\leftarrowtail} \psi \in EPL$, then

  b. $?(\phi \underset{\chi?}{\leftarrowtail} \psi) \in EQL$ and

  c. $?_{\chi?}\phi \in EQL$.

The constraint requiring the preliminary semantics of (44) is in the description of EPL, which is an extension of the predicate logical language PL that allows players to state answers to why-questions. $\phi \underset{\chi?}{\leftarrowtail} \psi$ is pronounced ⌜ϕ because ψ⌝, where the unpronounced $\chi?$ represents the contextually determined contrast-class for the why-question. The semantic constraint prevents $\chi?$ not properly related to ϕ from appearing as the contrast-class. In the remainder of the paper, we repress the contrast-class $\chi?$ in the symbol $\underset{\chi?}{\leftarrowtail}$ when it does not lead to ambiguity. (Note that $\underset{\chi?}{\leftarrowtail}$ is a relation between propositions rather than a truth-functional connective.)

EQL is an extension of the query language QL that allows players to pose why-questions and their yes-no counterparts, in addition to the yes-no and constituent questions already expressible in QL. $?(\phi \leftarrowtail \psi)$ is pronounced ⌜ϕ because ψ?⌝ and $?_{\chi?}\phi$ is pronounced ⌜why ϕ?⌝, with the contrast class $\chi?$ again going unpronounced. An alternative representation of the why-question might be $?\Phi(\phi \leftarrowtail \Phi)$, where ? binds a second-order variable Φ that ranges over meanings of sentences of PL.[81] Clearly, the proper (not merely preliminary) semantics of PL must be given before it would be clear what such a variable could range over, but since the variable would only occur bound in the formulae of EQL, an assignment function for second-order variables would never be needed. Nevertheless, issues about propositional variables are sidestepped by simply not representing the queried item.[82] (Note that this move is unavailable for the QL part of EQL, since the ? binds free variables already present in ϕ, and $?\vec{x}\phi$ for ϕ with no free-variables is a yes-no question.)

[81] Contra, e.g., Grover (1972), which argues for propositional variables taking *sentences* as substituends. But see (64-c), where the semantics of $?_{\chi?}\phi$ is given using quantification over sentences.

[82] Issues about the syntax of why-questions are also sidestepped. But cf. the denial that why-questions bind mid-sentence traces in chapter 7 of Bromberger (1992), which appeals to putative evidence that might be taken to have an alternative pragmatic explanation.

The syntax of EQL limits players to asking **simple** why-questions, since players can only ask $?_{\chi?}\phi$, with ϕ a sentence $\in PL$ and $\chi? \in QL$, and can only answer $\phi \leftarrowtail \psi$ with ψ also a sentence $\in PL$. In natural language, bare 'why?' in response to $\ulcorner\phi$ because $\psi\urcorner$ is ambiguous between (at least) $\ulcorner$why $\psi?\urcorner$ and $\ulcorner$why ϕ because $\psi?\urcorner$, but players can only ask the former. That is, players in search of "more complete" explanations are able to ask $\ulcorner$why $\psi?\urcorner$ in response to $\ulcorner\phi$ because $\psi\urcorner$, but not $\ulcorner$why ϕ because $\psi?\urcorner$. This limitation results from our definition of EQL, and is intended to keep the liberal characterization of players' individual relevance relations uncomplicated. In principle there is no reason why the limitation could not be lifted.[83]. But the lifting of that limitation would plausibly necessitate further restrictions on the nature of individual relevance relations. For example, it seems reasonable to think that the contextual R should be such that answers to why-questions about answers to simple why-questions should be about the background theory or the part of it used in evaluating an answer to the why-question, van Fraassen (1980)'s $K(Q)$. The general elucidation of such restrictions is non-trivial, as it requires a mechanism that specifies $K(Q)$ in addition to the usual determination of what kinds of responses are acceptable.

Now, the formulae of EQL are divided into **indicatives** and **interrogatives**. The formulae of EPL are the indicatives of EQL. The indicatives $\in EPL{-}PL$ are called **explanatory indicatives**. Formulae in $EQL{-}EPL$ are the interrogatives of EQL. The interrogatives $\in EQL - QL$ are called **explanatory interrogatives**. The explanatory interrogatives of the form $?_{\chi?}\phi$ are called **why interrogatives**. The symbols ϕ, ψ, etc. are meta-variables ranging over all formulae of EQL. $\phi!, \psi!$, etc. are meta-variables ranging over the indicatives of EQL; $\phi?, \psi?$, etc. are meta-variables ranging over the interrogatives of EQL. A sequence of formulae $\phi_1; \ldots; \phi_n$ is called (the proceedings of) an **inquiry**, with the meta-variable τ ranging over (possibly empty) sequences.

Because the semantics for explanatory indicatives and explanatory interrogatives depends on contextual factors, contexts must be discussed before the semantics can be given.

[83]The result would be formulae like $?_{?_{\chi?}\phi}\phi \underset{\chi?}{\leftarrowtail} \psi$, pronounced $\ulcorner$Why ϕ because $\psi?\urcorner$

4.2 Contexts in the Extended Game of Interrogation

Traditionally contexts are thought of as sets of possible worlds that represent what is known by the CPs. Groenendijk (1999) complicates the model by giving contexts the additional job of representing the issues raised by interrogatives, as well as the data provided by indicatives, in the course of the conversation. To accomplish this, contexts are structured by a symmetric, transitive relation C on the set of possible worlds, which are for Groenendijk first-order models of the predicate language PL chosen: C relates two worlds just in case they agree with all of the data provided and agree on all of the issues that have been raised. (Consequently, C relates a world to itself if and only if the world agrees with all of the data supplied.) van Fraassen (1980) requires an even more complicated model, since his contexts are to fix contrast-classes and relevance relations for why-questions. This requires several adjustments, which will be worked out in the course of meeting three challenges. First, the set of possible worlds on which the context operates cannot be populated by first-order models, for the formulae of EPL are not all first-order. Second, sources of contrast-classes and relevance relations must somehow be supplied. Third, since contexts fix relevance relations, and relevance relations in turn fix what explanatory indicatives can be given in response to a why-question, the context at any given point can actually fix what future contexts are allowed. The first and second challenges will be met in §4.2.1 and §4.2.2, respectively. But meeting the third challenge requires an inductive definition of admissible contexts, which induction proceeds by starting with initial admissible contexts and showing how the various pertinent EQL-formulae change the context. Since, following Groenendijk (1999), the semantics to be given is basically one in terms of context-change potential, this presupposes a semantics for EQL-formulae, in addition to presupposing an account of what it is for an EQL-formula to be pertinent. Therefore, after the basic characterization of contexts in §4.2.2 and a comment on the contribution of background theories in §4.2.3, QL-formulae and relevance relations receive treatments in §4.3.1 and §4.3.2, respectively, which allows for the formulation of a semantics for EQL-formulae in §4.3.3. §4.4 then covers pertinence and, finally, the admissible contexts are characterized §4.5.

4.2.1 Admissible Worlds

To begin, it is evident that first-order models are not satisfactory worlds for the semantics of EQL, for explanatory formulae are not assigned interpretations within them. But any first-order model $\mathcal{M}$ can be associated with a function from the sentences (closed formulae) of PL to $\{0,1\}$, namely, the characteristic function of $Th(\mathcal{M})$. By extending such a function to the sentences of EPL, worlds for the semantics of EQL can be produced. The extension of functions in $\{0,1\}^{\{\phi:\phi \text{ a sentence of } EPL\}}$ to admissible worlds is subject to the restrictions in (46), which allow them to serve as the basis for a semantics for the explanatory formulae of EQL.

(46) A world $w \in \{0,1\}^{\{\phi:\phi \text{ a sentence of } EPL\}}$ is **admissible** if

a. $w \upharpoonright PL$ is the characteristic function of $Th(\mathcal{M})$ for a first-order model $\mathcal{M}$ with domain D;

b. for all $\phi \underset{\chi?}{\leftarrowtail} \psi \in EPL$, if $w(\phi \underset{\chi?}{\leftarrowtail} \psi) = 1$, then $w(\phi) = w(\psi) = 1$; and

c. for $\Psi = \{\psi : w(\phi \underset{\chi?}{\leftarrowtail} \psi) = 1\}$, if $\psi_1, \psi_2 \in \Psi$, then $\psi_1 \wedge \psi_2 \in \Psi$, i.e., $w(\phi \underset{\chi?}{\leftarrowtail} (\psi_1 \wedge \psi_2)) = 1$.

The set of admissible worlds is called W.

The restriction in (46-a) ensures that admissible worlds assign values to the sentences of PL in accordance with the intended meanings of the logical symbols occurring in them. Thus, if a world w is such that $w(\phi) = w(\psi) = 1$, for ϕ, ψ sentences of PL, then $w(\phi \wedge \psi) = 1$ as well, and similarly for other connectives and quantifiers. The restriction in (46-b) imposes a standard condition on explanations, viz., that an explanans (as well as the explanandum, though this is usually too obvious to be said) must be true. (However, in light of the truth-conditions for explanatory indicatives adumbrated above and given below, it is best to think of 1 as representing intersubjective acceptability or assertability rather than truth.) (46-c) constrains the admissible worlds so that, e.g., if ψ_1 and ψ_2 both individually explain ϕ in an admissible world w, then their conjunction does as well. The restriction thus facilitates the interpretation of the $\leftarrowtail$ relation as picking out contextually complete answers. Provided only finitely many ψ are relevant to ϕ (relative to a given contrast-class), there will always be a *deductively strongest* ψ such that $\phi \leftarrowtail \psi$ holds at a world-context pair, which gives the **complete explanation** of ϕ relative to the contextually determined contrast-class at that world in that context, i.e., at that world according to the contextual R.

Note that the worlds are now basically partitions of EPL, not models.[84] Although admissible worlds are extensions of the characteristic functions of first-order models, in order to guarantee that each world is associated with a unique first-order model (i.e., to guarantee that the obvious function from admissible worlds to first-order models is many-one rather than many-many), the requirement had to be written into (46-a) that $\mathcal{M}$ has the domain D. This requirement will also appear in the official semantics for QL-formulae adopted in §4.3.1.

Also, it deserves mention here that the semantics to be given for EQL sentences is essentially contextual: it is not enough that $w(\phi \leftarrowtail \psi) = 1$ for $\phi \leftarrowtail \psi$ to be contextually acceptable. For ψ must also be judged relevant to ϕ (relative to its contrast class) by all CPs, in order for it to be intersubjectively acceptable. The partitioning of EPL by the worlds is then the basis of a necessary but not sufficient condition for the intersubjective acceptability of explanatory indicatives.

4.2.2 Structured Contexts with Memory

To incorporate sources for contrast-classes and relevance relations into the context, Groenendijk (1999)'s definition of context is adapted to (47). (However, only certain contexts will be admissible, a notion given an inductive definition in (72) below.)

(47) **Structured Contexts with Memory** A **context** K is a 5-tuple $\langle C, \tau, \kappa, T, P \rangle$, where

- C is a symmetric transitive relation on the set of possible worlds W
- τ is an initial segment of a history of a game
- $\kappa \preceq \tau$ is such that each $\phi \in \kappa$ is an interrogative[85]
- $T \subseteq EPL$ is a background theory
- P is a set of conversational participants or players

As in Groenendijk (1999), two worlds are contextually related by C if they agree with all data so far provided by indicatives in τ and agree with each other on all issues raised by interrogatives in τ. C is thus called a

[84] But cf. the use of *partitions determined by models* in Andrzej Wisniewski's UNILOG '2010 lecture slides, which I take to be a reasonably standard sort of move.

[85] $\preceq$ stands for '(is) a subsequence of'.

structured common ground, because it represents the traditional common ground as well as structuring it in terms of the issues that have been raised. The other elements of the context provide the mechanisms for fixing contrast-classes and relevance relations for why-questions.

τ and κ provide the mechanism for the context to supply contrast-classes for why-questions. τ keeps track of the players' previous utterances, and κ keeps track of interrogatives that have been asked and answered in the context.[86] To take care of van Fraassen (1980)'s central presupposition of why-questions, the rules of the game allow $?_{\chi?}\phi$ to be asked only if $\chi? \in \kappa$. (The restriction on admissible worlds in (46-b) together with the requirement on wff's that $[\phi] \in [\chi?]$ will ensure not only that ϕ is true, but also that its contrasts are false.)

T and P, along with the rest of a context K, form the basis of the mechanism that allows the contextual relevance relation R^K, which figures crucially in the semantics of explanatory indicatives (and therefore also explanatory interrogatives), to be fixed. The contextual relevance relation is fixed by these contexts, as shall shortly be seen, because individual CPs are taken to come with **worldviews**, which are functions from admissible contexts to individual relevance relations, from which the contextual relevance relation is derived by intersection as discussed in §3.3.3. The framework is thus appropriate as long as the only factors that affect how a CP answers a why-question are the structured common ground (C); the history of the conversation (τ), including the questions that have already been answered (κ); the background theory (T), part or all of which may not yet be common knowledge; and the CPs (P). Since both the CPs and the (structured) common ground in the form of P and C, respectively, are included among these factors, the framework allows CPs' answers to vary relative to some model they maintain of the likely knowledge and beliefs of other CPs.

Now that the role of each feature of context is understood, (48) presents the definitions of initial, absurd, and indifferent contexts. Note that $\langle w, w\rangle \in C$ is written $w \in C$.

(48) a. **Initial contexts** A minimal context is $K = \langle W^2, \emptyset, \emptyset, T, \{P_i, P_j\}\rangle$, an initial context of ignorance and indifference.
b. **Absurd contexts** An absurd context is $K = \langle \emptyset, \tau, \kappa, T, \{P_i, P_j\}\rangle$.

[86] κ is inspired by Ginzburg (2009)'s QNUD, a mechanism for keeping track of questions 'no longer under discussion' in a conversation.

c. **Indifferent contexts** An indifferent context is a K such that for all $w, v \in C$, $\langle w, v \rangle \in C$.

In these definitions, $P := \{P_i, P_j\}$ is the set of players of the game, with P_i the interrogator and P_j the witness. Because of the appearance of a background theory within a context, there are as many different minimal and absurd contexts K as there are background theories T. Part of the idealization of the model is that the Extended Game of Interrogation always starts from an initial context, so nothing is known at the beginning of the conversation. It is thus also part of the idealization of the model that the only common knowledge is what has been made explicit as part of τ, including what ordinarily would not need to be said, e.g., contextually available information like what is visible to CPs.

4.2.3 The Contribution of the Background Theory

Before moving on to meet the third challenge of characterizing admissible contexts, an additional job of T deserves mention. T is the background theory of the conversation in that CPs attempt to converse in terms of T, and to answer according to T.[87] But it is not presupposed that they know all of T, and they may be mistaken about parts of it. Indeed, as was just noted, games always start in an initial context of ignorance and indifference. There are many ways of implementing this constraint, but in this work only a very liberal implementation will be put in place. T is taken to be the set of sentences in EPL identified with a background theory.[88] (The identification of a theory with a collection of statements in (49) is a fairly standard move in the philosophy of science literature: it often precedes formation of the Ramsey sentence of T.[89]) Players' utterances will have to be countenanced by T:

(49) $\phi \in EQL$ is **countenanced by** T if, for each symbol occurring in ϕ excluding the logical connectives, first-order quantifiers, ?, and $\leftarrow\!\!\prec$, there is some $\psi \in T$ such that the symbol occurs in ψ.

[87] As pointed out during the question period of the defense of this thesis, one way to enhance this model to explain more interesting kinds of disagreement about the answers to why-questions would be to relativize background theories to individuals. Insofar as the background theories function in this thesis as both syntactic constraints and inputs into worldviews (and thereby partial determiners of relevance), CPs operating with different background theories are, in some sense, speaking different languages.

[88] T is $\subset PL$, just in case it does not include explanatory (including causal) claims.

[89] For a classic account of the formation Ramsey sentences, see Lewis (1970), 428-431.

This definition is intended to ensure that the notion of countenancing is as liberal as possible. The requirement that formuale in τ be countenanced by T will be incorporated into the logical notion of consistency, the implementation of the Gricean Maxim of Quality, which is meant to guarantee that the witness makes *credible* statements. (Note that utterances could also be constrained in a similar way much earlier in the process of model building, by choosing the signature of the predicate logical language such that its predicate and relation symbols are exactly those of T. But the present model is supposed to mirror natural languages in that it is possible for different conversations in the same language to have different operative background theories.)

4.3 Semantics for the Extended Game of Interrogation

The third challenge of characterizing admissible contexts can now be approached. But since admissible contexts are defined by induction based on extensions of τ, the definition presupposes accounts of both the context-change potentials of EQL-formulae and the allowable extensions of τ. That is, it presupposes accounts of both the *meanings* of EQL-formulae and the notion of an EQL-formula being *pertinent* in a context. The former account is presented piecewise in §4.3.1 and §4.3.3, treating QL-formulae and explanatory formulae, respectively, interrupted by §4.3.2, which covers the formal implementation of worldviews, individual relevance relations, and contextual relevance relations. The latter account appears in §4.4. The inductive definition of admissible contexts then comes in §4.5, by starting with the possible initial contexts and showing how contexts change when various pertinent EQL-formulae are added to τ.

4.3.1 Semantics for QL-formulae

The semantics for QL-formulae is easy to give: it is essentially that of Groenendijk (1999), which is based on a standard semantics for the underlying predicate language PL. It is defined in terms of the preliminary semantics supplied in (44) above.

(50) Semantics for QL-formulae

a. For $\phi! \in QL$, w an admissible world, K a context, g an assignment function from variables x_i to the fixed domain D, $[\![\phi]\!]_{w,K,g} =$

(i) 1 if $[\phi!]_{\mathcal{M},g} = 1$ where $\mathcal{M}$ is the first-order model with domain D such that $w \restriction PL$ is the characteristic function of $Th(\mathcal{M})$

(ii) 0 otherwise.

b. For $\phi!, K, g$ as above, $[\![\phi!]\!]_{K,g} =$
$\{w : w$ an admissible world s.t. $[\![\phi!]\!]_{w,K,g} = 1\}$

c. For $?\vec{x}\phi \in QL$, w, K, g as above, $[\![?\vec{x}\phi]\!]_{w,K,g} =$
$\{v : v$ an admissible world s.t. $\forall \vec{e} \in D^n([\![\phi]\!]_{w,K,g[\vec{x}/\vec{e}]} = [\![\phi]\!]_{v,K,g[\vec{x}/\vec{e}]})\}$

d. For $?\vec{x}\phi, K, g$ as above, $[\![?\vec{x}\phi]\!]_{K,g} = \{[\![?\vec{x}\phi]\!]_{w,K,g} : w$ an admissible world$\}$.

The semantics given here is essentially the preliminary semantics. Importantly, as revealed by (51), the context K makes no contribution to the semantics of QL-formulae.

(51) **Fact**: For all $\phi \in PL$, $[\![\phi]\!]_{w,K,g} = w(\phi[x_i/g(x_i)])$

(52) **Fact**: For all $\phi \in QL$, $[\![\phi]\!]_{w,K,g} = [\![\phi]\!]_{w,K',g}$ for all contexts K, K'.

From (52) it should be clear that no problems arise from providing the contextual semantics ahead of the specification of admissible contexts.[90] (Like Groenendijk (1999), then, the semantics abstracts from any van Rooy (2003)-style contextual mechanism for filling out underspecified meanings.)

Recall that the preliminary semantics was used in (45), the definition of EQL, to ensure that the only explanatory indicatives that could be formed would represent appropriate contrast-classes for their explananda. (53) now shows that either the preliminary or the official semantics for QL-formulae could have been used to enforce this condition.

(53) **Fact**: For all $\phi!, \psi? \in QL$, $[\![\phi!]\!]_{K,g} \in [\![\psi?]\!]_{K,g}$ iff $[\phi!]_g \in [\psi?]_g$.

(In the characterization of relevance relations to come in §4.3.2, to ensure that appropriate contrast-classes are involved, it is required that $\phi! \underset{\chi?}{\leftarrow\!\!\prec} \psi! \in EPL$, thus piggy-backing on the relevant constraint as it appeared in (45).)

[90] Alternatively, $[\![\cdot]\!]^*_{w,K,g}$ could be defined for all contexts as in (50), and $[\![\cdot]\!]_{w,K,g}$ could be introduced subsequent to the definition of admissible contexts, identified with the former evaluation but defined only for admissible contexts.

Finally, notice that the official semantics is more difficult to give without a fixed domain D. Without tying admissible worlds w to first-order models with domain D, $w \upharpoonright PL$ could underdetermine which first-order model w was supposed to extend, and (50-c) would need to be replaced by a new semantics. ((50-a) basically survives in any case, since any number of elementarily equivalent models $\mathcal{M}_i$ such that $w \upharpoonright PL$ is the characteristic function of $Th(\mathcal{M}_i)$ have the decency to agree on $\phi!$ by definition of elementary equivalence.) In the bad case, where $w \upharpoonright PL$ is the characteristic function of $Th(\mathcal{M})$ for some infinite $\mathcal{M}$, then it is such for infinitely-many first-order models by the Löwenheim-Skolem Theorem. In such cases, the bounded universal quantification over $\vec{e}$ would have to be rewritten to take varying domains into account, a task which is happily set aside here. On a related note, g is henceforth dropped wherever possible to simplify notation.

4.3.2 Worldviews and Relevance

Now that the official semantics for the QL part of EQL has been given, it is possible to take the next step toward the official semantics for the rest of EQL. Each player P_i of the game has an individual relevance relation R_i^K, which can vary from context to context.

(54) An **individual relevance relation** R_i^K is a set of ordered pairs of the form $\langle [\![\psi!]\!]_K, \langle [\![\phi!]\!]_K, [\![\chi?]\!]_K \rangle\rangle$ s.t. $\phi! \underset{\chi?}{\leftarrow} \psi! \in EPL$ where

a. if $\Psi := \{\psi! : \langle [\![\psi!]\!]_K, \langle [\![\phi!]\!]_K, [\![\chi?]\!]_K \rangle\rangle\}$ is s.t. $\psi_1, \psi_2 \in \Psi$, then $\psi_1 \wedge \psi_2 \in \Psi$;

b. if $\langle [\![\psi!]\!]_K, \langle [\![\phi!]\!]_K, [\![\chi?]\!]_K \rangle\rangle \in R_i^K$, then $\exists \xi? \in QL$ s.t., for each $[\![\phi_j!]\!]_K \in [\![\chi?]\!]_K$, $\exists \sigma \in PL$ a sentence s.t. $[\![\sigma!]\!]_K \in [\![\xi?]\!]_K$ with $\langle [\![\sigma!]\!]_K, \langle [\![\phi_j!]\!]_K, [\![\chi?]\!]_K \rangle\rangle \in R_i^K$; and

c. if $\langle [\![\psi!]\!]_K, \langle [\![\phi!]\!]_K, [\![\chi?]\!]_K \rangle\rangle \in R_i^K$, then $\exists \xi!, \sigma!, \theta?$ countenanced by $T \in K$ s.t. $[\![\xi!]\!]_K = [\![\psi!]\!]_K$, $[\![\sigma!]\!]_K = [\![\phi!]\!]_K$, and $[\![\theta?]\!]_K = [\![\chi?]\!]_K$.

Two of the logical constraints on individual relevance relations motivated in §3.3.2 appear as (54-a) and (54-b). (The third appears just below as a condition on worldviews.) (54-c) is as close to a substantive constraint from the background theory that the present account enforces: propositions can only be relevant (or can only have other propositions be relevant to them, or can only be the contrast-classes for such propositions) if they are expressible in terms of the background theory. In what follows, $\Psi = \{\psi_1, \ldots : R\langle [\![\psi_\alpha]\!]_K, \langle [\![\phi]\!]_K, [\![\chi?]\!]_K \rangle\rangle\}$ is assumed to be finite.

To get from contexts to individual relevance relations, each player of the game is assumed to be associated with a worldview as defined in (55). As promised, (55-a) incorporates (32), and ensures that explanatory formulae receive a consistent semantics as a game progresses.

(55) A **worldview** for player P_i, V_i, is a function from admissible contexts $K = \langle C, \tau, \kappa, T, P\rangle$ to individual relevance relations R_i^K where

a. for any $K' = \langle C', \tau', \kappa', T, P\rangle$ s.t. τ is an initial segment of τ',

$$\{\psi! : \langle [\![\psi!]\!]_{K'}, \langle [\![\phi!]\!]_{K'}, [\![\chi?]\!]_{K'}\rangle\rangle \in V_i(K')\} =$$

$$\{\psi! : \langle [\![\psi!]\!]_{K}, \langle [\![\phi!]\!]_{K}, [\![\chi?]\!]_{K}\rangle\rangle \in V_i(K)\}.$$

Since each V_i is only defined on admissible contexts, its domain depends on the definition of admissible contexts in §4.5. But the V_i must be used to determine which contexts are indeed admissible. This works out because the specification of the domain of the V_i stays one step ahead of the appeals to the V_i.

To recover van Fraassen (1980)'s contextual relevance relation, written here with an index keeping track of its context as R^K, as a last step before the semantics for explanatory formulae can be given, the players' individual relevance relations are simply intersected.

(56) **Contextual Relevance Relation** $R^K := \bigcap_i R_i^K$

With this definition, the ground is prepared for the contextual semantics of the explanatory formulae of EQL.

4.3.3 Contextual Semantics for EQL-formulae

The formulae of $QL \subset EQL$ received their official semantics in 4.3.1. This sets the stage for the semantics of explanatory formulae.

(57) a. For all formulae of the form $\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi \in EQL$,

$$[\![\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi]\!]_{w,K,g} = 1 \text{ iff}$$

(i) $w(\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi) = 1$ (Veracity Condition); and

(ii) $R^K\langle[\![\psi]\!]_{K,g}, \langle[\![\phi]\!]_{K,g}, [\![\chi?]\!]_{K,g}\rangle\rangle$ (Relevance Condition)

Otherwise $[\![\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi]\!]_{w,K,g} = 0$.

b. For $\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi$ as above, $[\![\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi]\!]_{K,g} =$

$$\{w : w \text{ an admissible world s.t. } [\![\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi]\!]_{w,K,g} = 1\}.$$

c. For all formulae of the form $\neg(\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi) \in EQL$,

$$[\![\neg(\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi)]\!]_{w,K,g} = 1 - [\![\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi]\!]_{w,K,g}.$$

d. For $\neg(\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi)$ as above, $[\![\neg(\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi)]\!]_{K,g} =$

$$\{w : w \text{ an admissible world s.t. } [\![\neg(\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi)]\!]_{w,K,g} = 1\}.$$

e. For all formulae of the form $\phi \wedge \psi \in EQL$,

(i) $[\![\phi \wedge \psi]\!]_{w,K,g} = [\![\phi]\!]_{w,K,g} \cdot [\![\psi]\!]_{w,K,g}$ and

(ii) $[\![\phi \wedge \psi]\!]_{K,g} = [\![\phi]\!]_{K,g} \cap [\![\psi]\!]_{K,g}$

Both of the constraints in (57-a) arise naturally from the preceding discussion. (57-a-i) is the condition that $\phi \leftarrow\!\!\prec \psi$ is intersubjectively acceptable in context K only if it is not ruled out by the world in question. (57-a-ii) adds to this the condition that ψ be contextually relevant to ϕ relative to its contrast class $\chi?$. Whether the relevance condition holds is determined by the intersection of the output of the CPs' worldviews.

(58) **Fact**: $R^K\langle[\![\psi]\!]_K, \langle[\![\phi]\!]_K, [\![\chi?]\!]_K\rangle\rangle$ iff, for each CP P_i, $V_i(K) = R_i^K$

such that $R_i^K\langle[\![\psi]\!]_K, \langle[\![\phi]\!]_K, [\![\chi?]\!]_K\rangle\rangle$

Of course, (58) follows trivially from the definitions of worldviews and contextual relevance relations in (55) and (56), respectively.

Further, (59) shows that the standard condition that an explanans be true (better: intersubjectively acceptable) holds.

(59) **Fact**: If $[\![\phi \leftarrowtail \psi]\!]_{w,K,g} = 1$, then $[\![\phi]\!]_{w,K,g} = [\![\psi]\!]_{w,K,g} = 1$.

This fact follows trivially from the definition of admissible worlds in (46) together with(57-a-i).

The desired facts about the relations between topics, contrast-classes, and answers also hold as a result of earlier definitions.

(60) **Fact**: $[\![\phi \underset{\chi?}{\leftarrowtail} \psi]\!]_{w,K,g}$ is defined only if $[\![\phi]\!]_{K,g} \in [\![\chi?]\!]_{K,g}$.

(60), which guarantees that ϕ is a member of the contrast-class $\chi?$, trivially follows from (53) and the definition of the language in (45). (61) guarantees that all of ϕ's contrasts are false.

(61) **Fact**: If $[\![\phi \underset{\chi?}{\leftarrowtail} \psi]\!]_{w,K,g} = 1$, then for all ξ s.t. $[\![\xi]\!]_{K,g} \in [\![\chi?]\!]_{K,g}$, $[\![\xi]\!]_{K,g} = [\![\phi]\!]_{K,g}$ or $[\![\xi]\!]_{w,K,g} = 0$.

It follows from the definitions of $[\![\chi?]\!]_{w,K,g}$ and $[\![\chi?]\!]_{K,g}$ in (50-c) and (50-d), respectively. Additionally, (62) guarantees that there is a deductively strongest explanation available at each world-context pair.

(62) **Fact**: There is some θ such that $[\![\phi \underset{\chi?}{\leftarrowtail} \theta]\!]_{w,K,g} = 1$ and, for all ψ such that $[\![\phi \underset{\chi?}{\leftarrowtail} \psi]\!]_{w,K,g} = 1$, $\theta \models_{f.o.l.} \psi$.

This fact, which is of the utmost importance for the possibility of giving complete answers in a partition semantics for explanatory interrogatives, follows from (46-c), (54-a), the assumption that only a finite number of propositions are relevant to ϕ relative to $\chi?$, and the use of intersection in (56).[91]

[91]Note that the fact would also hold if a definition of the contextual relevance relation using union like (41) had been preferred.

Incidentally, since the only wff of the form $\phi \leftarrowtail \psi$ are such that ϕ and ψ are sentences, (63) also holds.

(63) **Fact**: For any two assignment functions from variables x_i to the fixed domain D, g, g', $[\![\phi \leftarrowtail \psi]\!]_{w,K,g} = [\![\phi \leftarrowtail \psi]\!]_{w,K,g'}$.

Having presented the main facts about the semantics for explanatory indicatives, the semantics for explanatory interrogatives is given in (64).

(64) a. For all formulae of the form $?(\phi \underset{\chi?}{\leftarrowtail} \psi) \in EQL$, admissible worlds w, admissible contexts K, and assignment functions g

$$[\![?(\phi \underset{\chi?}{\leftarrowtail} \psi)]\!]_{w,K,g} =$$

$$\{v : v \text{ an admissible world s.t. } [\![\phi \underset{\chi?}{\leftarrowtail} \psi]\!]_{w,K,g} = [\![\phi \underset{\chi?}{\leftarrowtail} \psi]\!]_{v,K,g}\}.$$

b. For $?(\phi \underset{\chi?}{\leftarrowtail} \psi), K, g$ as above, $[\![?(\phi \underset{\chi?}{\leftarrowtail} \psi)]\!]_{w,K} =$

$$\{[\![?(\phi \underset{\chi?}{\leftarrowtail} \psi)]\!]_{w,K,g} : w \text{ an admissible world}\}.$$

c. For all formulae of the form $?_{\chi?}\phi \in EQL$, w, K, g as above,

$$[\![?_{\chi?}\phi]\!]_{w,K,g} = \{v : v \text{ an admissible world s.t., for all sentences } \psi \in PL, [\![\phi \underset{\chi?}{\leftarrowtail} \psi]\!]_{w,K,g} = [\![\phi \underset{\chi?}{\leftarrowtail} \psi]\!]_{v,K,g}\}.$$

d. For $?_{\chi?}\phi, K, g$ as above, $[\![?_{\chi?}\phi]\!]_{K,g} =$

$$\{[\![?_{\chi?}\phi]\!]_{w,K,g} : w \text{ an admissible world}\}.$$

(64-a) and (64-b) give the obvious definitions for the extension and intension of the yes-no question $?(\phi \leftarrowtail \psi)$. (64-c) mirrors the definition of the extension of the non-explanatory interrogatives of EQL, with universal quantification over sentences replacing the quantification over n-tuples of elements of the fixed domain D, and (64-d) defines the corresponding intension. Note that one element of the intension is

$$\mathcal{V} := \{v : v \text{ an admissible world s.t., for all sentences } \psi \in PL, [\![\phi \underset{\chi?}{\leftarrowtail} \psi]\!]_{w,K,g} = 0\}$$

For these worlds, in context K, the why-question cannot be answered and should be rejected. But something related is known about the worlds in $\mathcal{V}$.

(65) **Fact**: Where $\Psi = \{\psi_1, \ldots, \psi_n : R\langle [\![\psi_i]\!]_K, \langle [\![\phi]\!]_K, [\![\chi?]\!]_K \rangle\rangle\}$, $v \in \mathcal{V}$ as defined above iff $[\![\bigvee_{i=1}^{n} \psi_i]\!]_{v,K} = 0$.

(65) follows from the semantics for $?_{\chi?}\phi$ in (64-c), the definition of $\mathcal{V}$, and the semantics for $\phi \underset{\chi?}{\leftarrowtail} \psi$ in (57-a). This fact accounts for van Fraassen (1980)'s identification of the third presupposition of why-questions, discussed in §3.1 above. Recall that the presupposition was not that a why-question is known to have a contextually relevant answer, but that it was not known not to have one. The presence of a block of the partition populated by worlds where the why-question is to be rejected is thus important for the formalization of van Fraassen's theory.

4.4 Logical Notions

As a last step before the admissible contexts can be characterized, this section treats the logical notions that govern the progression of the game, culminating in a logical notion of pertinence. Since the logical notions involve semantic as well as syntactic elements, and since the semantics of *EQL* is contextual, the logical notions are *context-relative*. This is a necessary departure from Groenendijk (1999), where the logical notions were defined relative to a sequence of *QL*-formulae τ. In fact, the departure is also necessary to take into account the effect of the background theory T, which appears in (66).

The first logical notion is consistency.

(66) a. $\phi!$ is **consistent** with $K = \langle C, \tau, \kappa, T, P\rangle$ iff
(i) $\exists\langle w, w\rangle \in C$ s.t. $w \in [\![\phi!]\!]_K$, and
(ii) $\phi!$ is countenanced by T.
b. $\phi?$ is **consistent** with $K = \langle C, \tau, \kappa, T, P\rangle$ if $\phi?$ is countenanced by T.

The idea behind (66), which is supposed to represent the Gricean maxim of quality, is that a move in the game should be credible. Therefore it must be both consistent with previous information provided and expressed in the language of the background theory. In the case of interrogatives, which are taken to provide no information, consistency reduces to being expressed in the language of the background theory. Forcing the game to be governed by this notion, however, leads to a limitation of the model. Where why-questions are motivated by surprise, like (34) and (35) in §3.3.2, the answers are likely not to be consistent with their contexts. The implementation of a sufficiently sophisticated mechanism to deal with revision of the common ground would, therefore, go hand in hand with a revision of this notion of consistency.

The next logical notion is entailment.

(67) a. $K = \langle C, \tau, \kappa, T, P \rangle \models \phi!$ iff, $\forall \langle w, w \rangle \in C$, $w \in [\![\phi!]\!]_K$.
b. $K = \langle C, \tau, \kappa, T, P \rangle \models \phi?$ iff $\{\langle w, v \rangle \in C : [\![\phi?]\!]_{w,K} = [\![\phi?]\!]_{v,K}\} = C$.

The idea behind (67), which is supposed to represent the Gricean maxim of quantity, is that moves in the game should be non-redundant and non-superfluous. The notion of entailment gives rise, as in Groenendijk (1999), to notions of informativeness and inquisitiveness.

(68) a. $K = \langle C, \tau, \kappa, T, P \rangle \not\models \phi!$ iff $\exists \langle w, w \rangle \in C$ such that $w \notin [\![\phi!]\!]_K$.
b. $K = \langle C, \tau, \kappa, T, P \rangle \not\models \phi?$ iff $\exists \langle w, v \rangle \in C$ such that $[\![\phi?]\!]_{w,K} \neq [\![\phi?]\!]_{v,K}$.

An indicative $\phi!$ such that $K \not\models \phi!$ will have the effect on C of removing $\langle w, w \rangle$ from C if $w \notin [\![\phi!]\!]_K$. A formula ϕ is **informative** iff there is some K such that ϕ has that effect on K; in such K, it is **informative in** K. An interrogative $\phi?$ such that $K \not\models \phi?$ will have the effect on C of removing $\langle w, v \rangle$ from C if $[\![\phi?]\!]_{w,K} \neq [\![\phi?]\!]_{v,K}$. A formula ϕ is **inquisitive** iff there is some K such that ϕ has that effect on K; in such K, it is **inquisitive in** K. To verbify these adjectives, an informative (in K) $\phi!$ **provides information (in** K**)**, and an inquisitive (in K) $\phi?$ **raises an issue (in** K**)**.

Next is licensing.

(69) a. $K = \langle C, \tau, \kappa, T, P \rangle$ **licenses** $\phi!$ iff, $\forall \langle w, v \rangle \in C$, if $w \notin [\![\phi!]\!]_K$, then $v \notin [\![\phi!]\!]_K$.
b. $K = \langle C, \tau, \kappa, T, P \rangle$ **licenses** $\phi?$ iff
(i) $\phi?$ is of the form $?\vec{x}\psi$ or
(ii) $\phi?$ is
- of the form $?(\phi \underset{\chi?}{\hookleftarrow} \psi)$ or $?_{\chi?}\phi$,
- $K \models \phi$, and
- where Ψ is as in (65) above, $K \not\models \neg(\bigvee_{i=1}^{n} \psi_i)$.

The idea behind (69), which is supposed to represent the Gricean maxim of relation, is that moves should be responsive to previous moves. For the witness, this means that his responses should address the interrogator's questions.[92] For the interrogator, it means his questions should be such as to actually arise in the context. For the interrogatives of QL, this is always taken to be the case. But for explanatory interrogatives, van Fraassen (1980)'s account of the arising in a context of a why-question has been incorporated. The requirement that $K \models \phi$ is van Fraassen's first presupposition, viz., that the topic of a why-question be true. By our implementation of contrast-classes, satisfaction of the first presupposition automatically guarantees satisfaction of the second, viz., that the topic's contextual contrasts be false. The requirement that $K \not\models \neg(\bigvee_{i=1}^{n} \psi_i)$ is his third presupposition, viz., that it not be known that a why-question has no contextually relevant answer.

These three notions are combined in the notion of pertinence.

(70) ϕ is **pertinent** in K iff
a. ϕ is consistent with K (Quality),
b. ϕ is not entailed by K (Quantity), and
c. ϕ is licensed by K (Relation)

Pertinence appears in the inductive definition of admissible contexts, which can now be given.

4.5 Admissible Contexts, or Context Change in the Game of Explanation

Since initial contexts appear in the induction as a basis case, the relevant definition from (48) is repeated here.

(71) **Initial contexts** A minimal context is $K = \langle W^2, \emptyset, \emptyset, T, \{P_i, P_j\}\rangle$, an initial context of ignorance and indifference.

And now the induction.

[92] The definition is only partially successful in this regard, since one way for K to license $\phi!$ is if $K \models \phi!$ or $K \models \neg\phi!$, i.e., if $\phi!$ is not informative in K (including the case where $\phi!$ is a tautology of PL) or if $\phi!$ is not consistent with K (including the case where $\phi!$ is a contradiction of PL). This complicates the characterization of answerhood in terms of licensing, given in §4.6.

(72) a. All initial contexts are admissible.

b. If $K = \langle C, \tau, \kappa, T, P\rangle$ is an admissible context,

(i) $\langle C', \tau; \phi?, \kappa, T, P\rangle$ where
- $\phi?$ is pertinent and
- $C' = \{\langle w, v\rangle \in C : [\![\phi?]\!]_{w,K} = [\![\phi?]\!]_{v,K}\}$

is an admissible context; and

(ii) $\langle C', \tau; \phi!, \kappa; \lambda, T, P\rangle$ where
- $\phi!$ is pertinent,
- $C' = \{\langle w, v\rangle \in C : w, v \in [\![\phi!]\!]_K\}$, and
- $\lambda = \psi_1?; \ldots$ is the largest sequence of interrogatives disjoint with κ such that
  - $\lambda \prec \tau$ and
  - for each $\psi_i? \in \lambda$, there is some $\chi!$ such that $[\![\chi!]\!]_K \in [\![\psi_i?]\!]_K$ and $\langle w, w\rangle \in C' \Rightarrow w \in [\![\chi!]\!]_K$.

is an admissible context

The significance of this long-awaited definition is that an interrogative $\phi?$ has identical effects on K regardless of whether or not it is explanatory, and likewise for $\phi!$. Hopefully it is obvious that (72-b) gives the effect of updating K with $\phi?$ in (72-b-i) and of updating K with $\phi!$ in (72-b-ii). Henceforth the effect of updating K with a formula ϕ is written $K[\phi]$. Significantly, all updates retain the so-called classical update property.

(73) For $K = \langle C, \tau, \kappa, T, P\rangle$, $K[\phi] = \langle C', \tau; \phi, \kappa; \lambda, T, P\rangle$, for possibly empty λ, with $C' \subseteq C$.[93]

Moreover, since $\Psi = \{\psi_1, \ldots : R\langle [\![\psi_\alpha]\!]_K, \langle [\![\phi]\!]_K, [\![\chi?]\!]_K\rangle\rangle\}$ is assumed to be of some finite size n, there is guaranteed to be a sentence of EPL that gives the complete explanation of ϕ relative to $\chi?$ in K.

(74) **Fact**: For any admissible context K and explanatory interrogative of the form $?_{\chi?}\phi$ such that $K[?_{\chi?}\phi]$ is an admissible context, there is some $\xi!$ of the form $\bigwedge_{i=1}^{m-1} (\phi \underset{\chi?}{\leftarrow} \psi_i) \wedge \bigwedge_{i=m}^{n} \neg(\phi \underset{\chi?}{\leftarrow} \psi_i)$ such that $K[?_{\chi?}\phi][\xi!] = \langle C, \tau, \kappa, T, P\rangle$ with $?_{\chi?}\phi \in \kappa$. In fact, $[\![\xi!]\!]_K \in [\![?_{\chi?}\phi]\!]_K$.

Such a conjunction of explanatory indicatives and their negations is a complete, exhaustive explanation of ϕ relative to $\chi?$ in K; thus it is a complete, exhaustive answer to $?_{\chi?}\phi$. (Hence, it is essential to the possibility of stating

[93] Cf. Groenendijk (1999), 49.

an exhaustive answer to a why interrogative in EQL that Ψ be finite.)

Updates with non-explanatory formulae affect C as in Groenendijk (1999). Figure 2 illustrates how updating a context K with explanatory formulae affects C. (Note that the structured common ground for the context $K[\phi_1]\ldots[\phi_n]$ is written $C[\phi_1]\ldots[\phi_n]$; that ψ_1, ψ_2, and $\psi_1 \wedge \psi_2$ express the only propositions K-relevant to $?_{\chi?}\phi$; and that $\xi := (\phi \underset{\chi?}{\leftarrow} \psi_1) \wedge \neg(\phi \underset{\chi?}{\leftarrow} \psi_2)$.)

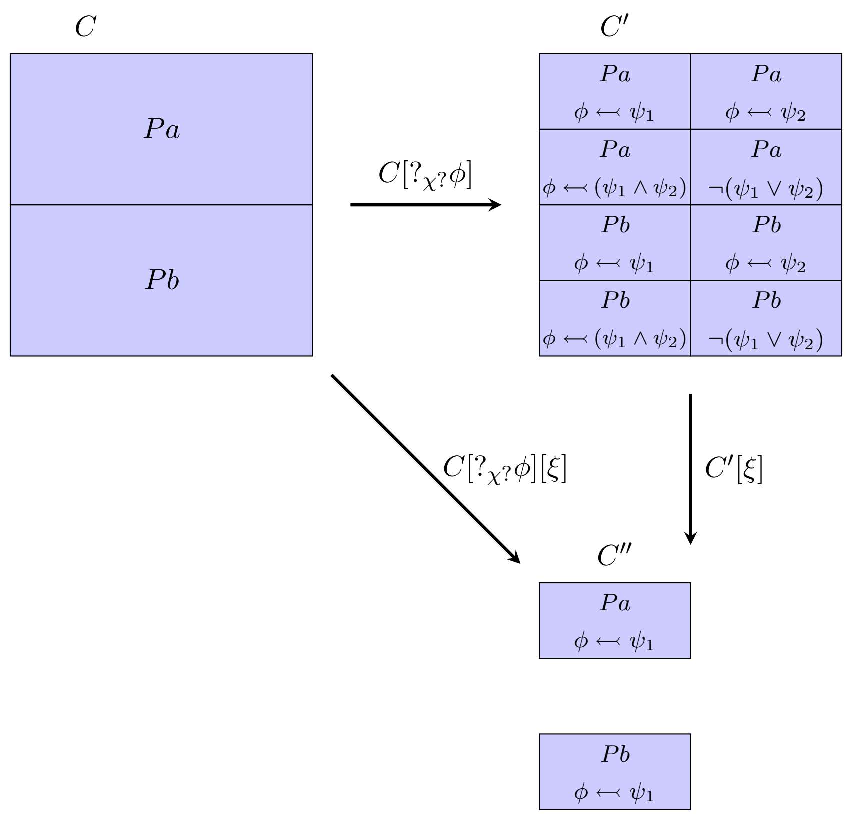

Figure 2: Updating K with explanatory formulae

In Figure 2, the initial $K = \langle C, \tau, \kappa, T, P\rangle$ is such that $?_{\chi?}\phi$ is pertinent. This reveals many facts about K:

(75) a. By the definition of pertinence, $?_{\chi?}\phi$ is licensed in K, so
- (i) $K \models \phi$ and
- (ii) where Ψ, defined as above, is a set of formulae with a

representative of each proposition relevant to ϕ relative to $\chi?$, $K \not\models \neg(\bigvee_{i=1}^{n} \psi_i)$.

b. Also by definition of pertinence, $?_{\chi?}\phi$ is not entailed by K, i.e., $K \not\models ?_{\chi?}\phi$. That is, there is some $\langle w, v \rangle \in C$ with $[\![?_{\chi?}\phi]\!]_{w,K} \neq [\![?_{\chi?}\phi]\!]_{v,K}$.
   (i) By definition of $[\![?_{\chi?}\phi]\!]_K$, then, there is no $\theta!$ such that $[\![\theta!]\!]_K \in [\![?_{\chi?}\phi]\!]_K$ and $\langle w, w \rangle \in C \Rightarrow w \in [\![\theta!]\!]_K$. So $?_{\chi?}\phi$ is not in κ.
   (ii) Neither, by (72), is $?_{\chi?}\phi$ in τ.

c. Again by definition of pertinence, $?_{\chi?}\phi$ is consistent with K, hence countenanced by T. This means that all non-logical symbols in $\chi?$ and ϕ appear in T.

(75) lists the conclusions that can be drawn about K from the fact that $?_{\chi?}\phi$ is pertinent in K: the pertinence in K of a why interrogative not only requires that it arises in K in van Fraassen (1980)'s sense, but also reveals something about τ, κ, and T. (P, for its part, contributes the worldviews of the players, which settles the K-intensions of explanatory formulae.) Of course, Figure 2 also depicts a situation where $\xi = (\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi_1) \wedge \neg(\phi \underset{\chi?}{\leftarrow\!\!\prec} \psi_2)$ is pertinent in $K' := K[?_{\chi?}\phi]$. The fact that ξ is licensed in K' actually follows from ξ being consistent with K', ξ not being entailed by K', and the fact that $?_{\chi?}\phi$ was not entailed by K, given the K-intensions of ξ and $?_{\chi?}\phi$. The relationship between licensing and the other facts just mentioned underlies the definition of answerhood in terms of licensing, finally to be made explicit in §4.6.

But first, the logical notions of §4.4 will be further illuminated.

(76) **Fact**: If $\phi!$ is countenanced by T but not consistent with $K = \langle C, \tau, \kappa, T, P \rangle$, then $\{\langle w, v \rangle \in C : w, v \in [\![\phi!]\!]_K\} = \emptyset$.

Attempting to update a context with an inconsistent (though countenanced by T) $\phi!$ would eliminate all worlds, because it would be inconsistent with the information already provided by previous utterances in τ. Attempting to update a context with a formula entailed by it, on the other hand, would be redundant or superfluous with respect to C.

(77) a. **Fact**: If $K = \langle C, \tau, \kappa, T, P \rangle \models \phi!$, then $\{\langle w, v \rangle \in C : w, v \in [\![\phi!]\!]_K\} = C$.

b. **Fact**: If $K = \langle C, \tau, \kappa, T, P \rangle \models \phi?$, then $\{\langle w, v \rangle \in C : [\![\phi?]\!]_{w,K} =$

$[\![\phi?]\!]_{v,K}\} = C$.

While the (77-b) just states one direction of the definition of entailment for interrogatives, (77-a) shows that effectively the same thing holds for entailed indicatives. Importantly, (76) and (77) amount to the fact that, if the pertinence requirements were removed from (72), the game could go wrong by eliminating all worlds from the structured common ground or by allowing moves that have no effect on the structured common ground. Thus for a context to be accessible according to (72), it must be played according to the rules of the game. In Groenendijk (1999), by way of contrast, contexts are defined independently of the logical notions that govern the game, and players obey the rules of the game only when all of their moves are pertinent.[94]

It is of note that, from (72), the desired facts about informativeness and inquisitiveness hold.

(78) **Fact**: Only indicatives can be informative, and only interrogatives can be inquisitive.

Before discussing licensing in §4.6, note that the appearance of τ and κ within K allows for the following fact about indifferent contexts:

(79) **Fact:** A context $K = \langle C, \tau, \kappa, T, P \rangle$ is indifferent if all interrogatives $\phi? \in \tau$ are also $\in \kappa$.

4.6 Licensing, Adequacy Tests, and Answerhood

In this section, it is shown that a number of tests passed by Groenendijk (1999)'s Game of Interrogation are also passed by the Extended Game of Interrogation, and that his notion of answerhood can be extended to why-questions.

Licensing is supposed to guarantee that moves are responsive to, i.e. logically related to, previous moves. An intuitive criterion for logical relatedness

[94]But note that it is also possible to define, say, possible contexts, by removing the pertinence requirements from (72), and then to define the logical notions relative to possible contexts, such that the admissible contexts are possible contexts obtainable from initial contexts by making only pertinent moves, i.e., by following the rules of the game, as these are enshrined in the logical notions. The order of presentation selected here was just to avoid any further multiplication of terminology.

to a context, as Groenendijk (1999) says, is that "if ϕ gives any information in the context at all, then ϕ at least partially resolves the contextual issues."[95] (Partially resolving an issue, in partition semantics, amounts to eliminating one of the blocks of the partition induced by the structured common ground.) An adequacy test for the notion of licensing, then, is that if ϕ's informativity in K guarantees its being resolvent in K, then K should license ϕ. The other direction of the desired result is actually a trivial consequence of the definition of licensing.

(80) **Fact**: If $K = \langle C, \tau, \kappa, T, P \rangle$ licenses ϕ, then:
if $\exists w : w \in C$ and $w \notin C[\phi]$
(if ϕ is informative in K),
then $\exists w \in C$: $\forall v : \langle w, v \rangle \in C \Rightarrow v \notin C[\phi]$
(then ϕ is resolvent in K).

But to pass the adequacy test, this is not the necessary direction. To get that direction, some kind of universal quantification over contexts is needed, because ϕ can be resolvent in K by eliminating random worlds from various parts of the partition induced by the structured common ground in addition to eliminating an entire part. Because meanings of formulae are context-dependent, however, this universal quantification has to be restricted to contexts that agree with K on the meanings of all the formulae in τ.

(81) **Fact (Adequacy Test)**: $K = \langle C, \tau, \kappa, T, P \rangle$ licenses $\phi!$ iff, for all admissible contexts $K' = \langle C', \tau', \kappa', T, P' \rangle$ such that $[\![\phi!]\!]_{K'} = [\![\phi!]\!]_K$, where $\tau^* \preceq \tau$ is the largest subsequence of τ such that $K[\tau^*]$ is an admissible context:
if $\exists w : w \in C'[\tau^*]$ and $w \notin C'[\tau^*][\phi!]$
(if $\phi!$ is informative in K'),
then $\exists w \in C'[\tau^*]$: $\forall v : \langle w, v \rangle \in C'[\tau^*] \Rightarrow v \notin C'[\tau^*][\phi!]$
(then $\phi!$ is resolvent in K').
(Proof is by induction on admissible contexts and τ. Fixing T for both K and K' is to ensure that formulae in τ are not excluded from τ^* merely in virtue of inexpressibility in the language of the background theory of K'.)

The right-to-left direction of (81) says that if $\phi!$ is always resolvent-if-informative after τ (provided formulae mean what they do in K), then $K = \langle C, \tau, \kappa, T, P \rangle$ licenses $\phi!$. That is, it ensures that the notion of licens-

[95] Op. cit., 52.

ing satisfies the intuitive notion of logical relatedness. ((81) is restricted to indicatives because interrogatives provide no information, so the resolvent-if-informative test intuitively says nothing about the logical relatedness of interrogatives.[96])

Like the Adequacy Test, Groenendijk (1999)'s Relatedness Test ensures that the definition of licensing for indicatives captures the desired notion.

(82) **Fact (Relatedness Test)**: K licenses $\phi!$ iff $K \models ?\phi$.

This fact makes manifest that indicatives are licensed exactly when asking the related yes-no question would be superfluous.

Like licensing, the notion of pertinence must also pass certain tests for the definition in (70) to be accepted.

(83) **Fact (Presupposition Test)**: $\neg\phi!$ is pertinent in K iff $\phi!$ is pertinent in K.[97]

In particular, it is important that (83) holds, since pertinence is "a notion of contextual appropriateness, where the latter is usually taken to relate to presuppositions."[98]

Given that licensing and pertinence pass these tests, they can be used to define logical notions of answerhood.

(84) For an admissible context $K = \langle C, \tau, \kappa, T, P\rangle$, $\phi!$ is an **answer in** K **to** $\psi?$ iff, for all admissible contexts K' s.t. $[\![\phi!]\!]_K = [\![\phi!]\!]_{K'}$ and $[\![\psi?]\!]_K = [\![\psi?]\!]_{K'}$, $\phi!$ is licensed in $K'[\psi?]$, and, for some such K', $\phi!$ is not licensed in K' but is licensed in $K'[\psi?]$.

Because meaning has been contextualized, so too must answerhood be. (84) requires that there be a context in which $\phi!$ is not licensed until $\psi?$ is asked in order to ensure that $\phi!$ is not licensed in K due to being a tautology or contradiction. Note that a non-contextual notion of answerhood can be

[96]In Groenendijk (1999), interrogatives are always trivially licensed. But since the notion of licensing defined in (69) incorporates van Fraassen (1980)'s account of a why-question arising in a context, the resolvent-if-informative adequacy test is restricted to the question of the licensing of indicatives.

[97]This definition is restricted to indicatives since $\neg(\phi?)$ is not a valid piece of syntax in either EQL or Groenendijk (1999)'s QL.

[98]Groenendijk (1999), 54.

recovered for non-explanatory formulae.

(85) **Fact**: If $\phi!$ is not an explanatory indicative ($\psi?$ is not an explanatory interrogative), $\phi!$ is an answer to $\psi?$ in all K iff $\phi!$ is licensed in $K[\psi?]$ for an initial context K.

Nevertheless, the unified notion of *answerhood in K* applies to all *EQL*-formulae. (Moreover, answerhood does not change due to subsequent happenings in an inquiry, by the condition imposed on worldviews in (55-a).)

In a context K, there are only two answers to a yes-no question.

(86) ϕ is an **answer in K** to $?\psi$ iff $[\![\phi]\!]_K = [\![\psi]\!]_K$ or $[\![\phi]\!]_K = [\![\neg\psi]\!]_K$.

This is actually an improvement over Groenendijk (1999), resulting from the additional requirement that there is a context in which ϕ is not licensed until $\psi?$ (here, $?\psi$) is asked.[99] Answers are guaranteed to be pertinent, as long as the information they impart has not already been imparted in the context.

(87) If $\phi!$ is an answer in $K = \langle C, \tau, \kappa, T, P\rangle$ to $\psi?$, then either $\phi!$ is pertinent or either $K \models \phi!$ or $K \models \neg\phi!$. In the former case, ϕ is called a **pertinent answer in** K to $\psi?$.

(88) **Fact**: $\phi!$ is a pertinent answer in K to $\psi?$ iff $\phi!$ is an answer in K to $\psi?$ and $K \not\models \phi!$ and $K \not\models \neg\phi!$.

That said, all of the basic facts about answerhood and pertinence transfer from Groenendijk (1999) to the Extended Game of Interrogation.

(89) Literal Answers:

a. $[\vec{c}/\vec{x}]\phi$ is an answer to $?\vec{x}\phi$

b. $\phi \underset{\chi?}{\leftarrow} \psi$ s.t. $R\langle[\![\psi]\!]_K, \langle[\![\phi]\!]_K, [\![\chi?]\!]_K\rangle\rangle$ is an answer to $?_{\chi?}\psi$.

(90) Negative Answers: ϕ is a (pertinent) answer in K to $\psi?$ iff $\neg\phi$ is a (pertinent) answer in K to $\psi?$.

(91) Conjoined Answers: If ϕ and χ are both answers in K to $\psi?$, then so is $\phi \wedge \chi$.

[99] Of course, an equivalent requirement could have been included there by quantifying over proceedings of inquiries rather than admissible contexts.

(92) Comparing Answers: Where ϕ, χ are pertinent answers in K to $\psi?$, ϕ is a **more informative answer in** K **to** $\psi?$ **than** χ iff $K[\phi] \models \chi$ and $K[\chi] \not\models \phi$.

(89) is important because it allows for partial answers, even though the underlying semantics of questions is a partition semantics, which typically requires complete answers to be given. (90) and (91) ensure that answerhood is preserved under propositional logical operations. And (92) allows for the characterization of the explicitly exhaustive answer in K to $\psi?$ as **optimal**, in that no other pertinent-in-K answers to ψ are more informative than it.

Given all of these results, it should be clear that the Extended Game of Interrogation really does extend the Game of Interrogation in a logical sense. A unified notion of contextual answerhood for all interrogatives of EQL is given, despite the pessimism of many theorists. Moreover, the fact that a non-contextual notion of answerhood can be recovered for non-explanatory indicatives is more a feature of the idealizations made in the model than a fact of life, as minimal reflection on van Rooy (2003) makes clear. But before going on to discuss directions for further research, including some meta-results that are lost as a result of the extension, it is time to present the 'constructive' alternative to the semantics thus far presented.

4.7 A Constructive Alternative

The problem with the semantics thus far presented is that not only are there complete explanations at world-context pairs, but there are also complete explanations just at worlds. This problem is a direct result of the definition of admissible worlds in (46). In this section, an alternative definition is adopted, and the main definitions in the Extended Game of Interrogation are adjusted as necessary, to avoid having complete explanations at worlds independent of contexts.

4.7.1 Constructing Admissible Worlds

The solution adopted is to identify worlds with partial functions from the sentences of EPL into $\{0, 1\}$ instead of total functions.

(93) A world $w \in \{0, 1\}^X$ is **admissible** if

a. $\{\phi : \phi$ a sentence of $PL\} \subseteq X \subseteq \{\phi : \phi$ a sentence of $EPL\}$;
b. $w \restriction PL$ is the characteristic function of $Th(\mathcal{M})$ for a first-order model $\mathcal{M}$ with domain D;
c. for all $\phi \underset{\chi?}{\hookleftarrow} \psi \in X$, if $w(\phi \underset{\chi?}{\hookleftarrow} \psi) = 1$, then $w(\phi) = w(\psi) = 1$;
d. for $\Psi = \{\psi : w(\phi \underset{\chi?}{\hookleftarrow} \psi) = 1\}$, if $\psi_1, \psi_2 \in \Psi$, then $\psi_1 \wedge \psi_2 \in \Psi$, i.e., $w(\phi \underset{\chi?}{\hookleftarrow} (\psi_1 \wedge \psi_2)) = 1$;
e. if $\phi \in Dom(w)$, then $\neg\phi \in Dom(w)$ s.t. $w(\phi) = 1 - w(\neg\phi)$; and
f. if $\phi, \psi \in Dom(w)$, then $\phi \wedge \psi \in Dom(w)$ s.t. $w(\phi \wedge \psi) = w(\phi) \cdot w(\psi)$.

The set of admissible worlds is called W.

As in (46), worlds are extensions of the characteristic functions of the theories of first-order models with domain D. This is guaranteed by (93-a)-(93-b). The now familiar condition that explanations be true (intersubjectively acceptable) is enshrined yet again in (93-c), and (93-d) is the first step to ensuring that contextually complete explanations will be available. The latter also has the effect of requiring X to be closed in the relevant way: in the notation of (93-d), $\Psi \subseteq X$ forces $\xi \in X$. (93-e) and (93-f) ensure that the partial functions are suitable as worlds.

Given this definition of admissible worlds, the definition of contexts, the semantics for the QL part of EQL, the treatment of relevance relations and worldviews, the contextual semantics for explanatory formulae, and the treatment of logical notions remains unchanged, with two adjustments to deal with explanatory formulae being undefined when not in the domain of a world. Thus, where the semantics for explanatory indicatives set $[\![\phi!]\!]_{w,K,g} = 0$ iff $[\![\phi!]\!]_{w,K,g} \neq 1$, in this constructive alternative, $[\![\phi!]\!]_{w,K,g}$ is undefined where $\phi! \notin Dom(w)$; the biconditional holds only where $\phi \in Dom(w)$. For explanatory interrogatives $\phi?$, the dynamics of context change ensures that $[\![\phi?]\!]_{w,K,g}$ will be defined. The next section makes this clear. Also, the definition of licensing for indicatives must be adjusted such that K licenses $\phi!$ iff $[\![\phi!]\!]_K$ is defined, and $\forall \langle w, v\rangle \in C$, if $w \notin [\![\phi!]\!]_K$, $v \notin [\![\phi!]\!]_K$.

4.7.2 Admissible Contexts

The inductive definition of admissible contexts substantially changes. When the interrogator puts why interrogatives to the witness, the worlds making up the structured common ground have to be extended so that their domains include all of the 'because' sentences that are relevant in the context. But by extending the domains as little as possible as the conversation progresses, there are no complete explanations true in worlds independent of contexts. That is, explanations only show up in worlds as the contextually complete ones are constructed.

(94) a. $\langle W \times W, \emptyset, \emptyset, T, P\rangle$ is an admissible context.

b. If $K = \langle C, \tau, \kappa, T, P\rangle$ is an admissible context,

(i) $\langle C', \tau; \phi?, \kappa, T, P\rangle$ where
- $\phi?$ is not an explanatory interrogative,
- $\phi?$ is pertinent, and
- $C' = \{\langle w, v\rangle \in C : [\![\phi?]\!]_{w,K} = [\![\phi?]\!]_{v,K}\}$

is an admissible context;

(ii) $\langle C', \tau; \phi!, \kappa; \lambda, T, P\rangle$ where
- $\phi!$ is pertinent,
- $C' = \{\langle w, v\rangle \in C : w, v \in [\![\phi!]\!]_K\}$, and
- $\lambda = \psi_1?; \ldots$ is the largest sequence of interrogatives disjoint with κ such that
  - $\lambda \prec \tau$ and
  - for each $\psi_i? \in \lambda$, there is some $\chi!$ such that $[\![\chi!]\!]_K \in [\![\psi_i?]\!]_K$ and $\langle w, w\rangle \in C' \Rightarrow w \in [\![\chi!]\!]_K$

is an admissible context;

(iii) $\langle C', \tau; \phi?, \kappa, T, P\rangle$ where
- $\phi?$ is an explanatory interrogative of the form $?(\phi \underset{\chi?}{\leftarrowtail} \psi)$,
- $\phi?$ is pertinent, and
- $C' = \{\langle w, v\rangle : w, v$ are admissible worlds with the smallest possible domain $\supseteq Dom(w_c) \cup \{\phi \underset{\chi?}{\leftarrowtail} \psi\}$ s.t. $w_c \in C$ and $[\![\phi?]\!]_{w,K} = [\![\phi?]\!]_{v,K}\}$

is an admissible context; and

(iv) $\langle C', \tau; \phi?, \kappa, T, P\rangle$ where
- $\phi?$ is an explanatory interrogative of the form $?_{\chi?}\phi$,
- $\phi?$ is pertinent, and
- $C' = \{\langle w, v\rangle : w, v$ are admissible worlds with domain $Dom(w_c) \cup \Psi$ s.t. $w_c \in C$ and $[\![\phi?]\!]_{w,K} = [\![\phi?]\!]_{v,K}\}$, where $\Psi = \{\psi_1, \ldots, \psi_n : R\langle [\![\psi_i]\!]_K, \langle [\![\phi]\!]_K, [\![\chi?]\!]_K\rangle\rangle\}$

is an admissible context.

Much of (94) is unchanged from the definition of admissible contexts in (72). But the clause for $\phi?$ is split into (94-b-i), which covers non-explanatory interrogatives and is unchanged from (72), and (94-b-iii) and (94-b-iv), which cover yes-no explanatory interrogatives and why interrogatives, respectively. (94-b-iii) says that the effect on $K = \langle C, \tau, \kappa, T, P \rangle$ of updating with a pertinent yes-no explanatory interrogative $?\phi$ is to extend the domain of the worlds in C to include ϕ and as much more as necessary to get to an $X \subseteq EQL$ such that $w \in \{0,1\}^X$ is an admissible world. (94-b-iv) says that the effect on $K = \langle C, \tau, \kappa, T, P \rangle$ of updating with a pertinent why interrogative is to extend the domain of the worlds in C to include Ψ, the set of relevant potential explanans for ϕ.

An illustration is again in order. To keep things to scale, Figure 3 begins

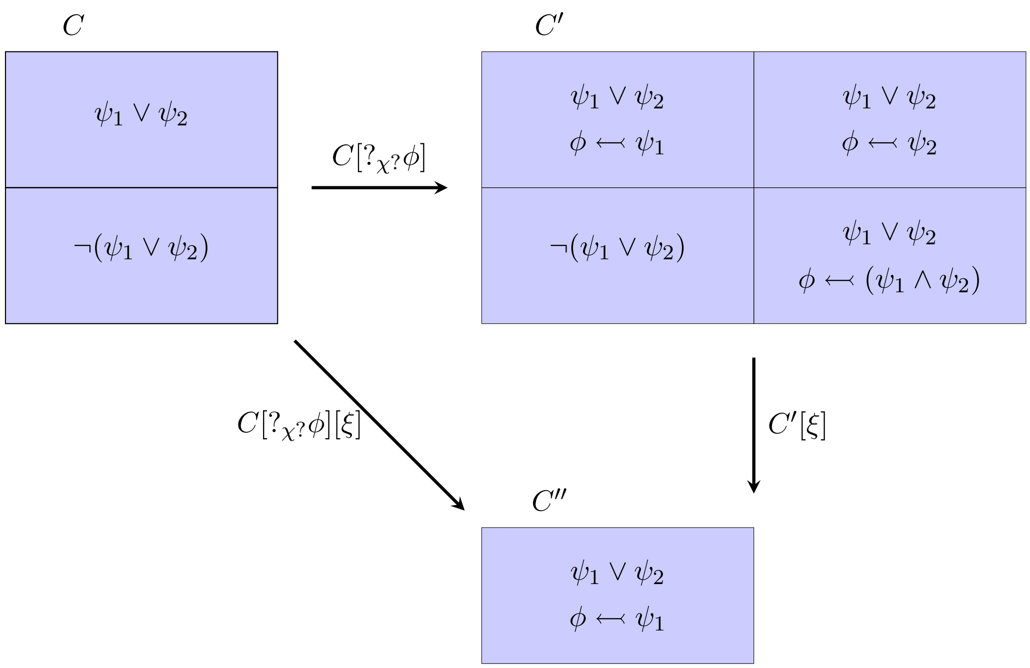

Figure 3: Constructively updating K with explanatory formulae

with a context $K = \langle C, \tau, \kappa, T, P \rangle$ such that $K \models ?(\psi_1 \vee \psi_2)$. Updating K with the why interrogative $?_{\chi?}\phi$ extends the domains of the worlds in C to include $\phi \underset{\chi?}{\longleftarrow} \psi_1$, $\phi \underset{\chi?}{\longleftarrow} \psi_2$, and $\phi \underset{\chi?}{\longleftarrow} (\psi_1 \wedge \psi_2)$. (So again, the only propositions K-relevant to $?_{\chi?}\phi$ are expressible by ψ_1, ψ_2, and $\psi_1 \wedge \psi_2$.) The resulting C' connects resulting worlds w and v only if $[\![?_{\chi?}\phi]\!]_{w,K} = [\![?_{\chi?}\phi]\!]_{v,K}$. Then updating with $\xi := \phi \underset{\chi?}{\longleftarrow} \psi_1 \wedge \neg(\phi \underset{\chi?}{\longleftarrow} \psi_2)$ eliminates all worlds with $[\![\xi]\!]_{w,K} = 0$.

As with Figure 2, the initial $K = \langle C, \tau, \kappa, T, P\rangle$ in Figure 3 is such that $?_{\chi?}\phi$ is pertinent, which again reveals many facts about K.

(95) a. By the definition of pertinence, $?_{\chi?}\phi$ is licensed in K, so
(i) $K \models \phi$ and
(ii) where Ψ, defined as above, is a set of formulae containing a representative ψ_i of each proposition relevant to ϕ relative to $\chi?$, $K \not\models \neg(\bigvee_{i=1}^{n} \psi_i)$.

b. Also by definition of pertinence, $?_{\chi?}\phi$ is not entailed by K, i.e., $K \not\models ?_{\chi?}\phi$. That is, there is some $\langle w, v\rangle \in C'$ with $\langle w, v\rangle \notin C$.[100]
(i) By definition of $[\![?_{\chi?}\phi]\!]_K$, then, there is no $\theta!$ such that $[\![\theta!]\!]_K \in [\![?_{\chi?}\phi]\!]_K$ and $\langle w, w\rangle \in C \Rightarrow w \in [\![\theta!]\!]_K$. So $?_{\chi?}\phi$ is not in κ.
(ii) Neither, by (94), is $?_{\chi?}\phi$ in τ.

c. Again by definition of pertinence $?_{\chi?}\phi$ is consistent with K, hence countenanced by T. This means that all non-logical symbols in $\chi?$ and ϕ appear in T.

Note that (95-b) is the only part of (95) that differs from (75), and even there the difference is only in how the non-entailment condition is restated. That small difference results, unsurprisingly, from the change from (72) to (94), but has no effect on the facts that $?_{\chi?}\phi \notin \kappa$ and $?_{\chi?}\phi \notin \tau$. It does, however, reflect the fact that the constructive semantics lacks the classical update property.

By (94), an explanatory indicative is defined in any context in which an explanatory interrogative to which it is relevant has been asked

(96) **Fact**: For an explanatory indicative $\xi := \phi \underset{\chi?}{\hookleftarrow} \psi$, $[\![\xi]\!]_{w,K,g}$ is defined in $K = \langle C, \tau, \kappa, T, P\rangle$ iff
a. $\xi \in Dom(w)$ and
b. either
(i) $?_{\chi?}\phi \in \tau$ and $R^K\langle[\![\psi]\!]_K, \langle[\![\phi]\!]_K, [\![\chi?]\!]_K\rangle\rangle$ or
(ii) $?(\xi) \in \tau$.

The final consideration about the constructive option to be noted here is its fidelity to the important results about licensing and answerhood, established

[100] That the entailment fails in this way should be surprising!

for the ‘non-constructive’ option in §4.6. It passes the Adequacy, Relatedness, and Presupposition Tests; the definitions of answerhood and pertinent answerhood apply; yes-no questions still have exactly two answers; the results about literal, negative, and conjoined transfer; and the comparison between answers can serve the same purpose of allowing for the characterization of the explicitly exhaustive answers as optimal.[101]

5 Loose Ends and Applications

This first part of this section discusses some questions about the logical nature of the framework. The next two offer some justification beyond the polemic of §1 for the lengths to which this thesis goes to give a partition semantics of why-questions: if the semantics is acceptable, the project could be profitable beyond its stated goals. The final part assesses the thesis in light of these considerations.

5.1 Meta-Logical Notes

Two comments, one extended, on the logic of the Extended Game of Interrogation (henceforth the Extended Logic of Interrogation, or ELoI) are in order. The first relates to meta-logical results established for Groenendijk (1999)'s Logic of Interrogation (LoI) by ten Cate and Shan (2006). The second relates to the quasi-intuitionistic character of the constructive option.

5.1.1 ten Cate and Shan (2006) and the Extended game of Interrogation

ten Cate and Shan (2006) established two results for LoI. The essential definitions and results from ten Cate and Shan (2006) are repeated here to facilitate the discussion of ELoI.[102]

The first result shows an intimate connection between entailment in LoI and Beth's Definability Theorem.

(97) Given a set Γ of first-order formulae, a **Γ-isomorphism** between two first-order models $\mathcal{M}$ and $\mathcal{N}$ such that for each formula $\phi(x_1, \ldots, x_n) \in \Gamma$, and for any sequence of individuals $d_1, \ldots, d_n$ in the domain of $\mathcal{M}$,

[101] Passing the Adequacy Test requires an obvious adjustment to account for cases where $[\![\phi!]\!]_K$ is not defined.

[102] There are slight variations in notation, spelling, and wording throughout.

we have $\mathcal{M} \models \phi[x_1/d_1, \ldots, x_n/d_n]$ iff $\mathcal{N}[x_1/f(d_1), \ldots, x_n/f(d_n)]$.[103]

(98) For Σ a first-order theory, Γ a set of first-order formulae, ψ a first-order formula, Σ **implicitly defines** ψ in terms of the formulae in Γ iff every Γ-isomorphism between two models of Σ is a $\{\psi\}$-isomorphism as well.[104]

(99) The entailment $\phi_1!, \ldots, \phi_n!, \chi_1?, \ldots, \chi_m? \models_{LoI} \psi?$ holds iff the set of asserted formulae $\{\phi_1!, \ldots, \phi_n!\}$ implicitly defines $?\vec{x}\psi$ in terms of $\{\chi_1?, \ldots, \chi_m?\} \cup \{x = c : c \text{ is a constant}\}$.[105]

In (99), the $\phi_i!$ can be taken as meta-variables ranging over sentences of PL, and the $\chi_i?$ and $\psi?$ as meta-variables ranging over interrogatives of QL, as PL and QL are defined in §4.1. A limited version of an analogous result holds for ELoI, when attention is restricted to the QL part of EQL.[106]

(100) For the proceedings of an inquiry τ, a set of formulae $\Gamma = \{\phi_1, \ldots, \phi_n\}$ is **τ-equivalent**, written $\Gamma \approx \tau$, if $\Gamma = \{\phi : \phi \in \tau\}$. Where $\tau \preceq \tau'$ (τ is a subsequence of τ') with $\Gamma \approx \tau$, $\Gamma \propto \tau'$.

(101) For $K = \langle C, \tau, \kappa, T, P \rangle$ admissible with the set of QL-formulae $\Delta = \{\phi_1!, \ldots, \phi_n!, \chi_1?, \ldots, \chi_m?\}$ s.t. $\Delta \propto \tau$, $K \models ?\vec{x}\psi$ iff the set of asserted formulae $\{\phi! : \phi! \in \Delta\}$ implicitly defines ψ in terms of $\Gamma = \{\chi_1?, \ldots, \chi_m?\} \cup \{x = c : c \text{ is a constant}\}$.

Proof: [$\Rightarrow$] Suppose $K \models ?\vec{x}\psi$. Let $f : \mathcal{M} \to \mathcal{N}$ be a Γ-isomorphism between $\mathcal{M} = (D, I)$ and $\mathcal{N} = (D, I')$, both models of $\{\phi_1!, \ldots, \phi_n!\}$. (Note that both models share the fixed D, as throughout this work, and that constants are assumed to be rigid designators, though the latter is guaranteed relative to the Γ-isomorphic models $\mathcal{M}$ and $\mathcal{N}$, by construction of Γ.) The goal is to show that f is a $\{\psi\}$-isomorphism also. Consider any $\langle w, v \rangle \in C$ s.t. $w \upharpoonright PL$ is the characteristic function of $Th(\mathcal{M})$ and $v \upharpoonright PL$ is the characteristic function of $Th(\mathcal{N})$. A simple inductive argument shows that $C[\phi_1!], \ldots, [\phi_n!], [\chi_1?], \ldots, [\chi_m?] = C$. Since $K \models ?\vec{x}\psi$, it follows

[103]Ibid., 66.
[104]Ibid., 66.
[105]ten Cate and Shan (2006), 67. Notation adjusted.
[106]The results in this section are for the non-constructive option, but nothing appears to change for the constructive option.

that $C[?\vec{x}\psi] = C$, so $[\![\psi]\!]_{w,K} = [\![\psi]\!]_{v,K}$. By choice of w and v, f is a ψ-isomorphism too.

[$\Leftarrow$] Suppose $\{\phi_1!, \ldots, \phi_n!\}$ implicitly defines ψ in terms of Γ, and consider admissible $K = \langle C, \tau, \kappa, T, P\rangle$ with $\Delta \propto \tau$. By definition of admissible contexts, $C[\phi_1!], \ldots, [\phi_n!], [\chi_1?], \ldots, [\chi_m?] = C$. To show $K \models ?\vec{x}\psi$, it suffices to show $C[?\vec{x}\psi?] = C$. Consider any $\langle w, v\rangle \in C$. Simple inductive arguments show that $[\![\phi_i!]\!]_{w,K} = [\![\phi_i!]\!]_{v,K} = 1$ and $[\![\chi_i?]\!]_{w,K} = [\![\chi_i?]\!]_{v,K}$ for every $\phi_i!, \chi_i? \in \Delta$. So the identity relation $i : \mathcal{M} \to \mathcal{N}$ s.t. $w \upharpoonright PL$ and $v \upharpoonright PL$ are the characteristic function of $Th(\mathcal{M})$ and $Th(\mathcal{N})$, respectively, is a Γ-isomorphism. By the definition of implicit definition, i is also a $\{\psi\}$-isomorphism. So $[\![?\vec{x}\psi]\!]_{w,K} = [\![?\vec{x}\psi]\!]_{v,K}$, i.e., $\langle w, v\rangle \in C[?\vec{x}\psi]$, i.e., $C[?\vec{x}\psi?] = C$.

However, no analogous result holds for EQL in general, because of the possibility of background theories according to which why-questions should be rejected. For a theory T according to which the why interrogative $\phi?$ should be rejected, $\Psi := \{\psi! : R^K\langle[\![\psi!]\!]_K, [\![\phi!]\!]_K, [\![\chi?]\!]_K\rangle\rangle\} = \emptyset$ in any initial context $K = \langle W^2, \emptyset, \emptyset, T, P\rangle$. So $K \models \phi?$ trivially, though obviously $\emptyset$ does not implicitly define $\phi?$ relative to $\emptyset$.

The second result shows that Groenendijk's logic is a conservative extension of first-order logic.

(102) $\phi_1!, \ldots, \phi_n!, \chi_1?, \ldots, \chi_m? \models_{LoI} \psi!$ iff $\phi_1!, \ldots, \phi_n! \models_{f.o.l.} \psi!$.[107]

Again, a limited version of an analogous result holds for ELoI, when attention is restricted to the QL part of EQL. (Since the proof is fairly trivial compared to the proof of (101), it is omitted.)

(103) For $K = \langle C, \tau, \kappa, T, P\rangle$ admissible with the set of QL-formulae $\Delta = \{\phi_1!, \ldots, \phi_n!, \chi_1?, \ldots, \chi_m?\}$ s.t. $\Delta \approx \tau$, $K \models \psi!$ iff $\phi_1!, \ldots, \phi_n! \models_{f.o.l.} \psi!$.

But again, no analogous result holds for EQL in general, because of the possibility of contexts in which why-questions should be rejected. The problem here is contexts where Ψ as defined above is either empty or where $\phi \leftarrow\!\!\prec \psi$ has been ruled out for each $\psi \in \Psi$.

[107] ten Cate and Shan (2006), 68.

(104) **Example**: An admissible context $K = \langle C, ?_{\chi?}\phi; \neg(\phi \underset{\chi?}{\hookleftarrow} \psi_1); \neg(\phi \underset{\chi?}{\hookleftarrow} \psi_2), \kappa, T, P\rangle$ where $\Psi := \{\psi! : R^K\langle [\![\psi!]\!]_K, [\![\phi!]\!]_K, [\![\chi?]\!]_K\rangle\} = \{\psi_1, \psi_2\}$ is such that $K \models \neg(\psi_1 \vee \psi_2)$. (In fact, $\kappa = ?_{\chi?}\phi$.)

As witnessed by (104), ELoI is not a conservative extension of classical first-order logic when explanatory formulae are involved.

5.1.2 Intuitionistic Logic and the Constructive Option

It was already noted that the constructive version of ELoI lacks the classical update property. It also behaves non-classically with respect to explanatory indicatives, for which the law of excluded middle fails.

(105) **Fact**: $\exists K$ an admissible context, $\exists \phi! := \phi \underset{\chi?}{\hookleftarrow} \psi$ an explanatory indicative, s.t. $K \not\models \phi! \vee \neg\phi!$.

Witnesses for (105) include any context $K = \langle C, \tau, \kappa, T, P\rangle$ where no explanatory interrogative $\phi?$ is $\in \tau$.

Moreover, that the law of excluded middle holds for non-explanatory indicatives is an artifact of the attempt to build ELoI on top of LoI. But once a constructive semantics for why-questions is in the picture, it becomes more natural to try to build it on top of an intuitionistic logic for constituent questions, and future work should explore doing so.

5.2 Why-Questions and Counterfactuals

Since Lewis (1973a) drew attention to a previously under-appreciated facet of Hume's discussion of causation, the dominant framework for philosophical analyses of causation reduced causal facts to the truth-values of related counterfactuals. For C to have caused E, the basic account goes, is for it to be the case that, if C had not happened, E would not have happened. Any such account clearly requires that the truth-values of counterfactuals are logically prior to causal facts. But Kment (2006) impressively argues that the right account of the truth-values of counterfactuals is actually logically posterior to causal (and, more generally, explanatory) facts. Following Lewis (1973b), Kment takes the truth-value of a counterfactual ⌜if P had been the case, Q would have been the case⌝ to depend on what the 'closest' worlds in which P is true are like. The counterfactual is true iff all of the closest antecedent-worlds are also consequent-worlds, i.e., if Q too is true in them.

But Kment differs from Lewis in that Kment's account of closeness invokes explanatory (and therefore also causal) notions, whereas Lewis studiously avoids them.

(106) If some fact f obtains in both of two worlds, then this similarity contributes to the closeness between the two worlds if and only if f has the same explanation in both worlds. (In the special case in which f has no explanation in either world, this condition counts as vacuously satisfied.)[108]

The theoretical advantage of (106) is that it provides an explanation of the well-known temporal asymmetry phenomenon, whereby counterfactuals are normally only true if the consequent occurs later in time than the antecedent. (106) also has the distinct advantage of answering a question that had been left unanswered by one of the primary works in one of the other major theories of counterfactuals, the premise semantics tradition inaugurated by Veltman (1976).[109] In the form that tradition took in Veltman (1985), a 'premise function' fixes a set of important propositions (premises) in each world, and a counterfactual is true at a world if all the antecedent-worlds in which a maximal subset of the set of important propositions holds are also consequent-worlds. The question left unanswered by Veltman (1985) is what membership in the set of important propositions requires. Although space does not allow a sustained argument, it seems that (106) helps here. Briefly, if the set of important propositions, relative to an antecedent, is the set of true propositions such that there is some antecedent-world in which their truth has the same explanation as in the actual world, then the examples that troubled Veltman (1985) seem to be covered.

(107) Consider a man—call him Jones—who is possessed of the following disposition as regards wearing his hat. If the man on the news predicts bad weather, Mr. Jones invariably wears his hat the next day. A weather forecast in favor of fine weather, on the other hand, affects him neither way: in this case he puts his hat on or leaves it on the peg, completely at random. Suppose, moreover, that yesterday bad weather was prognosed, so Jones is wearing his hat. In that case: If the weather forecast had been in favor of fine weather, Jones would have been wearing his hat.[110]

[108] **?**, 282.
[109] I rely on the discussion of this tradition in Chapter 5 of Schulz (2007) in what follows.
[110] Schulz (2007), 97.

The counterfactual is false, since Jones might not have been wearing his hat, had the forecast been in favor of good weather. But Veltman (1985) gets (107) wrong. It does so because the set of important propositions for a world w is taken to be an individual's "stock of beliefs in w" and indeed Jones is believed to be wearing his hat in w. (106) seems to help here in that it is clear that the explanation of Jones's wearing his hat in w is that the weather was forecast to be bad, whereas Jones's wearing his hat in antecedent-worlds has no such explanation. (According to the description of the case, it would have no explanation at all in such worlds.) Truth of the antecedent disturbs the explanation of Jones wearing his hat, so the fact that Jones was wearing his hat cannot be in the set of important propositions, according to the revision being suggested. Complicating the issue, seriously but not necessarily irredeemably, is that the function that chooses these sets of important facts is thus clearly antecedent-relative.[111] Nevertheless, (106) is of great interest in that it has something to offer to two major traditions in the semantics of counterfactuals.

Kment (2006) leaves an important issue unresolved, though, and that is where the material in this thesis enters. Kment notes that the precise sense of the term 'explanation' in (106) is problematic. While he favors there some form of what Salmon (1984) called the ontic conception of explanation, no way of narrowing down the notion seems to do. If the relevant notion is that of a *complete* explanatory history, the left-to-right direction of (106) is false, as the discussion quoted in (108) shows.

(108) Suppose that the king tosses a fair coin and it comes up heads. On the eve of the coin toss, a would-be assassin who is about to plant a bomb at the royal palace is poisoned by his enemy x. x's action is an element of the complete explanatory history of the king's coin toss, since it prevented the assassin from killing the king and thereby interfering with the causal process that led up to the coin toss. Hence, in a world in which a different person, y, poisons the assassin, the complete explanatory history of the coin toss is different. And yet we want to say that the coin toss would have yielded the same outcome if the assassin had been poisoned by y rather than by x.

Since people typically judge the considered counterfactual to be true, the relevant sense of 'explanation' cannot be that of a complete ontic explana-

[111]Cf. the discussion of antecedent-closeness in the appendix of Kment (2006).

tion. Neither, however, can it be limited to the *productive* ontic explanation, for then the right-to-left direction of (106) will be false.

(109) Suppose that Nixon's missile system is indeterministic. When the button is pushed, there is some chance of a nuclear explosion and some chance that the signal will fizzle out. In this case, we want to say that there might have been a nuclear explosion or the signal might have fizzled out if Nixon had pressed the button. Explosion-worlds and fizzling-worlds are equally close. But note that there are countless matters of particular post-antecedent fact that obtain both in the chancy-fizzling world and in our world. And yet, since the world with chancy fizzling is no closer than the world with nuclear war, the extra post-antecedent similarities in the chancy-fizzling world must be irrelevant to closeness.

It seems, happily, that the sense of explanation according to which an explanation is a complete answer to a why-question does better here. For it seems that (110) should receive the same answer regardless of who poisoned the king's would-be assassin.

(110) Why did the coin toss yield the outcome it did?

It seems safe to say that a contextually complete answer to (110), even one that mentions the would-be assassin, would not mention x or y, even in a context where the prompt from (108) has just been given. The identity of the assassin's poisoner is just irrelevant. Contrariwise, where t is the time of Nixon's counterfactual button pressing, (111) should receive a different answer in fizzling-worlds and the actual world.

(111) Why did event e, which took place in Moscow 24 hours after time t, occur?

The contextually complete answer to (111), in a context where the prompt from (109) was just given, had better mention the fizzling in the fizzling-worlds, though obviously not in worlds where Nixon did not press the button. Since the intuitions about the answers to why-questions seem to systematically track the intuitions about the truth-values of counterfactuals, it is plausible that the correct sense of 'explanation' in (106) is that formalized in this thesis. (112) formalizes the proposal.

(112) Let f be a fact such that $\phi!$ says that f holds, $\psi!$ be the antecedent of a counterfactual, and $\xi? := ?_{\chi?}\phi!$. Further let

$K = \langle C, \ldots ; ?(\phi!); \ldots ; \phi!; \ldots ; \neg\psi!; \ldots ; \xi?, \kappa, T, P\rangle$ and
$K' = \langle C', \ldots ; ?(\phi!); \ldots ; \phi!; \ldots ; \psi!; \ldots ; \xi?, \kappa', T, P\rangle$ be admissible contexts. Then:

If some fact f obtains in the actual world w and an antecedent-world v, then this similarity contributes to the $\psi!$-closeness between the two worlds if and only if $[\![\xi?]\!]_{w,K} = [\![\xi?]\!]_{v,K'}$.

In the contexts of (112), it has been asserted that f holds. In the context K, the antecedent of the counterfactual to be evaluated has been denied.[112] In the context K', that antecedent has been affirmed. With the prompt of an example thus translated into a linguistic context, if the answer to $\xi?$, i.e., why does f hold?, is the same in both contexts, then its explanation for the purposes of (106) is the same in both w and v.

Obviously much remains to be done in future work, in order to pursue the suggestion formalized as (112). For one thing, the individual relevance relations were glossed in modal terms, as encoding what CPs would give or accept as answers. Care must be taken to ensure that explanations in the present sense can be prior to the truth-values of counterfactuals, given this modal language, if Kment (2006) is to be helped by the present notion of explanation. All that can safely be claimed here is that the intuitions about counterfactuals and the intuitions about contextually complete answers to why-questions track one another closely.

But there is a positive feature of the account that deserves emphasis in this connection. Answering a why-question seems to generate an implicature that, had the answer not been true, the topic of the why-question would not have been. Counterfactual analyses of causation have always had to grapple with problems that arise when, if a cause had not occurred, its effect would have occurred anyway. The problem arises, in some cases, because there are multiple, overdetermining causes. But since answers to why-questions can be exhaustive and complete, there is a semantic explanation of what goes wrong when such an implicature turns out to be false because of overdetermination. Namely, the answer to a why-question generates a false implicature in cases of overdetermination just in case it was partial. For it is a feature of the semantics that all relevant causes must be specified by a complete

[112] Thus, as stated, the proposal requires the antecedent of a counterfactual to be false. But of course it is possible to relax this requirement at this semantic level, if it is indeed a pragmatic phenomenon.

answer, regardless of whether or not they are overdeterminers.[113]

5.3 Causes and Context Sets

A second, much simpler, application for the account is in providing a semantics for the phrase 'the cause(s)'. Westerståhl (1984) offers a theory of determiners according to which 'the' is not a determiner, but rather "a context indicator which signals the presence of a context set X, in such a way that *the* A denotes $X \cap A$, the subset of A."[114] The observation to be made here is simply that, in a world w, for a context K, where A is the phrase ⌜cause of $\phi!$⌝, taking the context set

$$X := \{\psi! : \{\psi_1, \ldots, \psi_n : R\langle [\![\psi_i]\!]_K, \langle [\![\phi!]\!]_K, [\![\chi?]\!]_K \rangle\rangle \text{ and } [\![\psi_i]\!]_{w,K} = 1\}$$

seems to give the right results. Such an application is actually suggested by van Fraassen (1980), in his summary discussion of a few competing theories of explanation:

> (1) Events are enmeshed in a net of causal relations
> (2) What science describes is that causal net
> (3) Explanation of why an event happens consists (typically) in an exhibition of salient factors in the part of the causal net formed by lines 'leading up to' that event
> (4) Those salient factors mentioned in an explanation constitute (what are ordinarily called) the *cause(s)* of that event.

This second application, then, is the implementation of van Fraassen's suggestion that the causes of an event are just the salient factors, i.e., exactly what is mentioned in the contextually complete answer to a why-question about the event.

5.4 Ergo Cogito,

Although the mission is not yet accomplished, at least by now there seems to be reason to hope that it is not impossible. It remains to show in detail how to introduce substantive constraints on individual relevance relations or worldviews to limit the semantics to particular kinds of why-questions. Based on the partial taxonomy of §3.3.2, modeling the belief states of CPs

[113] A similar result might hold for cases of preemption, depending on what future studies reveal about how people answer why-questions after being presented with suitable prompts.

[114] Op. cit., 60.

will be an important source of constraints for many kinds of why-questions. Corpus studies can be expected to illuminate these kinds, and whether sophisticated models of beliefs are sufficient for them. But in some cases, the constraints will relate to elements of contexts other than the CPs. For the special case of scientific why-questions with deductive-nomological explanations as answers, for example, the proceedings of an inquiry and the background theory together will determine whether an answer has to contain a statement of a law from the background theory, or whether such a statement has already appeared in the course of the inquiry. It is possible that a more structured representation of the background theory will have to be made a part of contexts to implement such constraints. The important point is that it should now be relatively easy to introduce this kind of sophistication, for a unified, contextualized notion of what it is to be an answer to a question has been extended to include a framework for why-questions in general. For linguists and those computer scientists who are interested in how to scale up partition semantics to include something more than yes-no and constituent questions, the presentation of the framework will, hopefully, have been instructive.

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