Triggering Presuppositions [*]

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Abstract. While presuppositions are often thought to be lexically encoded, researchers have repeatedly argued for 'triggering algorithms' that productively classify certain entailments as presuppositions. We provide new evidence for this position and define a new triggering rule. On the empirical side, we show that presuppositions are productively generated from iconic expressions that one may not have seen before, which suggests that some triggering algorithm is indeed called for. Turning to normal words, we show that sometimes a presupposition p is triggered by a simple or complex expression that does not even entail p: it is only when contextual information guarantees that the entailment goes through that the presupposition emerges. On standard theories, this presupposition could not be hardwired, because if so it should make itself felt (by way of projection or accommodation) in all cases. Rather, a triggering algorithm seems to take as an input a contextual meaning, and to turn some contextual entailments into presuppositions. On the theoretical side, we propose that an entailment q (possibly a contextual one) of an expression qq' is treated as a presupposition if q is an epistemic precondition of the global meaning, in the following sense: usually, when one learns that qq' (e.g. *x stops q-ing*), one antecedently knows that q (e.g. *x q-ed*). Presuppositions thus arise from an attempt to ensure that information that is cognitively inert in general experience is also trivial relative to its linguistic environment. On various analyses, q is trivial in its linguistic environment just in case q is entailed by its local context; this provides a direct link between presupposition generation and presupposition projection.

1 Introduction

1.1 Goals

Most presupposition research of the last 50 years has focused on the Projection Problem: taking as given the presuppositions of elementary expressions, how are those of complex sentences derived from the meanings of their parts?[1] This leaves another question open: why do some expressions trigger presuppositions in the first place? While this is often taken to be an irreducibly lexical fact, several researchers have argued that this is insufficiently explanatory and possibly incorrect, hence a 'Triggering Problem': given some information that a linguistic expression conveys about the world, can we predict which part is at-issue and which part is presupposed?

To make things concrete, we can start from theories (such as Heim 1983a) in which a presupposition failure yields a third truth value # (besides 'true' and 'false'). To state the Triggering Problem in concrete terms, we take as input information about the situations in which an expression is true vs. non-true, and we seek to predict which of the 'non-true' situations yield failure, i.e. the third truth value #, as is illustrated in (1).

(1) Triggering algorithm: input-output relation

An explicit rule that achieves this result is a triggering algorithm. It will be useful in this discussion to call 'bivalent content' of an expression the bipartition between 'true' and 'non-true' that is obtained by lumping together falsity and presupposition failure, as is done on the left side of (1). The Triggering Problem is thus to predict the presupposition of an expression once its bivalent content has been specified.

This article has two main goals. First, we summarize recent and new data that highlight the need for a triggering algorithm, for two reasons: presuppositions are productively generated from iconic expressions one may not have encountered before, hence a productive mechanism is called for; in addition, a presupposition *p* is sometimes triggered by a conventional word that does not even entail *p*: it is only when contextual information guarantees that the entailment goes through that the presupposition emerges. Both lines are argumentation are illustrated in (2).

(2) a. This light bulb, are you going to UNSCREW-ceiling_____? (Schlenker, to appear)
     => this light bulb is on the ceiling
     b. Will this hunter pull the trigger?
     => this hunter's rifle is loaded

In (2)a, the verb is replaced with a gesture of unscrewing a bulb from the ceiling (transcribed as *UNSCREW-ceiling*). Even if one hasn't seen this gesture before, it conveys information about the position of the bulb. Crucially, this information is treated as a presupposition, and since this couldn't be a lexical fact, a triggering algorithm is needed to explain why this is so. In (2)b, *pull the trigger* generates the presupposition that the rifle is loaded. But neither *pull*, nor *the*, nor *trigger* can lexically encode such a presupposition. Furthermore, one can perfectly well pull the trigger of a rifle that's not loaded. But common sense knowledge guarantees that *when a hunter pulls the trigger, the rifle is loaded*. The latter inference is presupposed: this is an instance of a presupposition triggered on the basis of contextual information.

Our second goal is to propose a new triggering rule. In a nutshell, a contextual entailment *q* of of an expression *qq'* is treated as a presupposition if *q* is an epistemic precondition of the global meaning, in the following sense: usually, when one learns that *qq'* (e.g. *x stops q-ing*), one antecedently knows that *q* (e.g. *x q-ed*). Importantly, the situations in which one learns that *qq'* may be entirely non-

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linguistic: one may observe by direct perception that it rains at t-1 ($= q$), and then that it doesn't rain at t ($= q'$). In this case, upon learning qq' at t, one had an antecedent belief that it rained before.

The general intuition that presuppositions are in some sense entailments that count as 'preconditions' is an old one;[2] but the content we give to this concept is new. In our analysis, presuppositions arise from an attempt to ensure that information that is cognitively inert (because it is antecedently known) in general, often non-linguistic experience is also trivial relative to its linguistic environment. On various analyses, p is trivial in its linguistic environment just in case p is entailed by its local context (e.g. Stalnaker 1974, Heim 1983a, Schlenker 2009); this provides a direct connection between presupposition generation and presupposition projection.

1.2   Characterizing presuppositions

What are presuppositions? They are typically characterized by two properties: (i) they have a particular *epistemic status*, in that they are typically taken for granted by conversation participants; and (ii) they display a characteristic projection behavior, in the sense that they interact in specific ways with logical operators. The epistemic status of presuppositions is a difficult diagnostic to use because there are numerous cases of informative presuppositions (see for instance Stalnaker 2002, von Fintel 2008, Schlenker 2012), as in *I'll pick up my sister at the airport*: nothing tragic happens to my utterance if my interlocutor didn't previously know that I have a sister. By contrast, projection behavior typically serves to characterize presuppositions, as is illustrated in (3).

(3)   a. John knows that he is incompetent.
        => John is incompetent
        b. Does John know that he is incompetent?
        => John is incompetent
        c. John doesn't know that he is incompetent.
        => John is incompetent
        d. If John knows that he is incompetent, he'll get depressed.
        => John is incompetent
        e. John might know that he is incompetent.
        => John is incompetent
        f. None of these ten students knows that he is incompetent.
        => each of these ten students is incompetent

The inference obtained in (3)a just shows that *John knows that he is incompetent* conveys the information that John is in fact incompetent. What classifies this inference a presupposition is the fact that, unlike standard entailments, it is preserved in questions, under negation, *if*, and *might*; and that under *none*-type quantifiers, it gives rise to a universal presupposition that each of the relevant individuals is incompetent.[3] We will rely on projection tests to characterize presuppositions in the rest of this piece.

1.3   Presupposition projection and local triviality

While there are diverse accounts of presupposition projection (see for instance Beaver and Geurts 2011 and Schlenker 2016 for surveys), one particularly influential idea is that the presupposition of an expression is a component of its meaning that 'wants' to be trivial relative to its local context. A seminal observation was that the conjunction *John is incompetent and he knows that he is* does not carry a presupposition although its second conjunct does. Stalnaker 1974 proposed that this is because the local context of the second conjunct incorporates information contributed by the first conjunct, with the result that the presupposition is automatically satisfied. From this perspective, a theory of presupposition projection is in essence a theory of how local contexts are computed. Stalnaker 1974 sketched a pragmatic mechanism based on belief update, but it proved hard to generalize beyond a couple of connectives. Heim 1983a thus took the very meaning of operators to be instructions to

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[2] See for instance Simons 2001, Thomason et al. 2006, Abusch 2010. As Abusch 2010 explicitly notes, an explicit and general definition of what a 'precondition' has remained elusive.
[3] See for instance Chemla 2009 for experimental data; Beaver 2001 argued instead for weaker patterns of existential projection in this case.

construct local contexts, hence a dynamic semantics for presupposition projection.

In this framework, an elementary clause $\underline{p}p'$ with presupposition p (whose presuppositional status is marked by underlining) and at-issue component p' is evaluated relative to a context set C as in (4)a, and yields a failure if p isn't true throughout C, and otherwise yields the set of p'-worlds within C.

(4)   a. If $\underline{p}p'$ an elementary clause with presupposition p and at-issue component p', and if C is a context set, C[$\underline{p}p'$] = # iff C = # or for some world w in C, p is false in w. If C[$\underline{p}p'$] ≠ #, C[$\underline{p}p'$] = **{w ∈ C: p' is true in w}**.
      b. If F and G are two clauses, and if C is a context set, C[F and G] = (C[F])[G]

To obtain a general theory of presupposition projection, one needs to recursively define the ways in which various connectives affect the context set. For instance, a context set C updated with *F and G* is the successive update of C with *F*, and then with *G*, as illustrated in (4)b. Within dynamic semantics, this approach is very general and can be extended to any connective or operator. Outside of dynamic semantics, Schlenker 2009 showed how local contexts can be reconstructed once the syntax and bivalent meaning of a sentence has been specified; this has the advantage of doing away with lexical stipulations pertaining to the dynamic behavior of connectives (but see Rothschild 2011 for a different way of constraining dynamic semantics).

The idea that a presupposition ought to be locally trivial has thus become a cornerstone of several solutions to the Projection Problem. We will now suggest that it might also provide a key to the Triggering Problem.

1.4   Presuppositions as epistemic preconditions

In effect, solutions based on local contexts posit that presuppositions should be cognitively inert: once their linguistic environment is taken into account, they should make no contribution whatsoever. This property is exemplified in (4)a, where the presuppositions play no role at all in the output set (boldfaced); rather, the sole function of the presupposition is to trigger cases of semantic failure. But cognitive transparency could in principle be a much more general phenomenon. With an eye to the behavior of *Sam knows that it's raining*, suppose that at time t one acquires the belief that *it is raining and Sam correctly believes this*; this means that at t-1 one didn't hold this belief, and in principle either conjunct (*it is raining, Sam believes it*) could be responsible for this fact. But in many cases, one's knowledge of facts will precede one's knowledge of Sam's beliefs about them, for instance because one has more information about what is going on in the world than in Sam's head. If so, in most cases, one knows that it is raining before learning that Sam correctly believes that it is. This is another way of saying that believing that it is raining is often an epistemic precondition for believing that Sam knows that it is raining.

This leads us to a proposal: presuppositions arise because entailments that are usually cognitively inert in non-linguistic experience should also be inert (trivial) relative to their linguistic environment. An informal statement is provided in (5)a and a more formal one in (5)b.

(5)   **Presuppositions as epistemic preconditions**
    a. Informal statement
    If E is a propositional expression uttered relative to a context c', and if p is an entailment of E relative to c', treat p as a presupposition if, when one antecedently believes that c' and one acquires the belief that E, one typically antecedently believes that p.
    b. Formal statement (with discrete time)
    For some contextually provided threshold a: If E is a propositional expression uttered relative to a context c', and if c' |= E => p, treat p as a presupposition (and thus require that c' |= p) in case:
    $P(believe_{t-1}$ **p** | $believe_{t-1}$ c' and $acquire_t$ **E**) ≥ a
    where *P(F | G)* is the conditional probability of F given G, and *$acquire_t$ E* abbreviates: *not believe_{t-1} E and believe_t E*.

To illustrate, upon learning that someone unscrewed a bulb from the ceiling, one would typically antecedently know that the bulb was on the ceiling, hence the presupposition in (2)a. In this case, the triggering rule can be applied to any expression, including new 'words' that one may never have seen before. In addition, our basic rule can be made sensitive to the meaning of an expression relative to a local context, and thus it can turn contextual entailments into presuppositions. In (2)b, *this hunter pulled*

the trigger contextually entails that the rifle was loaded. Typically, upon learning that a hunter pulled the trigger (and shot), one would antecedently have known that the rifle was loaded, which explains why this contextual entailment is turned into a presupposition.

The analysis crucially hinges on the way in which one discovers facts about the world. To illustrate the importance of the discovery process, a minimal pair might help. Without negation, both gestural verbs in (6) entail that the agent has a gun with/next to him. But in (6)a, if one witnessed the scene, one would have an antecedent belief about the presence of a gun, which is depicted as being on the table. By contrast, in (6)b, the gun is depicted as being originally hidden in the agent's jacket, and thus one would not typically have an antecedent belief about its existence. This predicts, plausibly in this case, that (6)a presupposes the presence of a gun whereas (6)b doesn't.

(6)   The situation will be tense, but the person sitting next to me will not

   a. PICK-UP-GUN-SHOOT_   https://youtu.be/-WRpDdgVfOA

   => the person sitting next to me will have a gun in front of him

   b. PULL-GUN-SHOOT_   https://youtu.be/yObse1dBMJ4

   ≠>? the person sitting next to me will have a gun in his jacket

While our analysis could systematically be made sensitive to the entire syntactic and pragmatic context of an expression, we will propose a more articulated account in which the decision to turn an entailment into a presupposition is made relative to the most general context that guarantees that the entailment goes through. As a result, for expressions, such as *know,* which lexically entail the truth of their complement, the determination will only have to be made once, relative to the common sense knowledge that is shared across conversations. For *pull the trigger*, a more specific context will have to be used, since we will need to guarantee that *x pulls the trigger* contextually entails that the relevant weapon was loaded. The advantage of this presentation is twofold: first, it makes it easier to compare the proposed account to lexical theories of triggering, which also do the work only once for expressions like *know*. Second, some systematic problems arise if we make the account too context-sensitive (there are also arguments *for* a highly context-sensitive theory; we will leave this issue largely open).

Importantly, our analysis is not stated directly in terms of the probabilities of certain entailments, but rather in terms of the probability that one antecedently believed them upon acquiring certain richer beliefs. One might posit instead that presuppositions are just entailments that are very likely to be true. This would make different and incorrect predictions. Take *Will Sam DRINK-LARGE?*, where *DRINK-LARGE* is a two-handed gesture of drinking from a large bowl. The presuppositional component is that *Sam is holding a large bowl,* while the at-issue component is that *x drinks*. But here what is surprising is plausibly that Sam should be holding a large bowl, not that Sam should be drinking: presupposing the high probability entailment would yield the wrong result. By contrast, our analysis in terms of epistemic preconditions yields reasonable results: on the assumption that one learns that (at t) x drinks from a bowl, there is a good chance one antecedently knew that (at t) x is holding a bowl (for instance in cases in which knowledge is acquired by direct perception).[4]

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[4] Two additions might be helpful. Concerning the terminology: instead of *one acquires the belief that F* and *one antecedently believed that p*, which are a mouthful, we will often say: *one learns that F*, and *one knew that p*. Concerning the data: the argument from *DRINK-LARGE* can easily be replicated with other gestures. In (10)below, we summarize experimental data from Tieu et al. 2019 that show that a gesture of turning a wheel, as in *Will Sally TURN-WHEEL?*, presupposes that the agent is next to a wheel. One can make the wheel size implausibly large and small, and the inferential facts don't change. In other words, the presupposition may be extremely surprising, which yields an argument against a simple-minded probabilistic account. But it remains that upon learning that x turned a wheel, one probably antecedently knew that x was next to a wheel, as is expected by the present analysis.,

1.5   Structure

The rest is this article is organized as follows. We start by presenting old and new arguments in favor of the existence of a triggering algorithm: traditional arguments pertain to explanatory adequacy and cross-linguistic stability; new arguments pertain to iconic constructions and 'part-time triggers', which trigger presuppositions only when some contextual assumptions are satisfied (Sections 2-3). We review three notable analyses of the Triggering Problem, outlining challenges for each (Section 4).[5] We then state our main proposal, illustrate it, and defend some of its general predictions (Sections 5-7). Turning to the focus-sensitive triggers *only* and *even*, we argue that our triggering rule can explain a large part of their presuppositional behavior; these are particularly important case studies because some readings of *only* and *even* make reference to expectedness/probability while others don't, and we make fine-grained predictions about the typology of presuppositional patterns (Section 8). We then sketch an extension of the analysis to presuppositions that are triggered by an overt or covert anaphoric component, including in the case of *too* (Section 9). Finally, we discuss broader extensions and alternatives (including in terms of counterfactual rather than probabilistic reasoning), and draw some conclusions (Sections 10-11).[6] Throughout, we base our discussion on plausible probabilistic differences between discovery processes, such as those in (6)a vs. (6)b; evaluating these probabilities in a more rigorous fashion is something we do not attempt in this piece.

The structure of the theory is depicted in (7): the existence of a triggering algorithm is motivated by traditional consideration (overgeneration of lexicalist accounts) and new data (iconic triggers, contextual triggers, complex triggers). The form of the triggering algorithm is motivated the projection algorithm (= entailments that tend to be inert in cognitive life should be trivial in their linguistic environment). The analysis derives desirable results for a variety of verbal triggers, as well as for *only* and *even*. With the addition of a treatment of referential failure, it extends to *the*, *she$_i$*, and *too$_i$/in addition to this$_i$*.

(7)   Structure of the theory
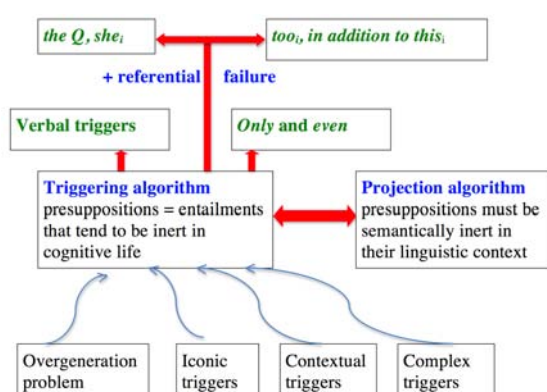
2   The need for a triggering algorithm I: productivity

2.1   Traditional arguments

Why should one seek a presupposition triggering algorithm? Three types of arguments often come to mind. First, it is more explanatory to derive presuppositions from a general algorithm than to stipulate them on a word-by-word basis. To put things concretely, if we underline presuppositional contributions, *stop*, *continue* and *start* can be represented as in (8).

(8)   a. x stops q-ing   = <u>x q-ed</u>; x doesn't q

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      b. x continues q-ing   = <u>x q-ed</u>; x q's
      c. x starts q-ing   = <u>x didn't q</u>; x q's

In each case, information pertaining to what happened before the evaluation time is presupposed; information pertaining to the evaluation time is at-issue. The question is why there couldn't be lexical entries, such as those in (9) for *stop*, which provided the same global information (i.e. had the same bivalent content) but divided it differently among the presuppositional and at-issue components, for instance by presupposing nothing, or by presupposing information conveyed about the time of evaluation.[7]

(9)   a. x stops* q   = x q-ed; x doesn't q
        b. x stops** q   = x q-ed; <u>x doesn't q</u>

Abrusán 2011 offers a solution, reviewed below. The triggering rule we will argue for does as well: when one acquires the belief that *x stops q-ing at t*, i.e. that *x q-ed before t and x doesn't q at t*, one usually antecedently believes that *x q-ed before t* (because one is likely to know more about earlier states; this will be in particular the case if information grows by way of direct perception).

      The second traditional argument in favor of a triggering algorithm is that one might be missing generalizations by encoding presuppositions on a word-by-word basis. The data might well allow for a more predictive theory, as researchers often have the impression that there is little cross-linguistic variation across triggers: in terms of the schematic representation in (1), there is a general impression that whenever two words *w* and *w'* have the same bivalent content, they also divide it in similar ways between the at-issue and presuppositional components. For instance, English *stop* and *cease* have roughly the same bivalent meaning as French *arrêter* and *cesser*, and all trigger a presupposition about the initial state, as in (8)a. Tonhauser 2017 makes this point more rigorously about Swahili and Guaraní. (we come back to potential counterexamples in Sections 4.1).[8]

2.2   *Arguments from pro-speech gestures*

In order to show that there exists a triggering algorithm, it would be optimal to display cases in which one generates presuppositions *from words that one has never encountered before*: this would guarantee that the presuppositions observed are not due to a pre-existing lexical entry. But if the words have not been encountered, how can we tell what they mean? With standard words, the problems is difficult to solve.[9] But if one uses gestures instead of words, their iconic nature may suffice to make their informational content clear upon first exposure, including in cases in which one has not encountered the gesture before (this is the case because iconic representations are based on productive principles, as outlined for instance in Greenberg 2013, 2018 for the semantics of pictures).

      While most gesture research has focused on *co*-speech gestures, Schlenker 2019, to appear and Tieu et al. 2019 investigate instead *pro*-speech gestures, which fully replace words instead of

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[7] Abrusán 2011 provides an account that is particularly well-suited to analyze change of state verbs; we revisit it in Section 4.3.

[8] An additional argument is that presuppositions might or might not be generated depending on fine-grained pragmatic considerations. Thus Stalnaker 1974 argued that some presuppositions that are generated in the third person, as in(i)a, fail to be generated in the first person, as in (i)b.

(i)   a. If she realizes later that I have not told the truth, I will confess it to everyone.
         b. If I realize later that I have not told the truth, I will confess it to everyone.

Whether this is exactly the right characterization is still under debate, but remarks that go in the same direction can be found in Beaver 2010. Be that as it may, pragmatic dependency is an argument that ought to be handled with care. Uncontroversially, presuppositions can, at some cost, be converted into an at-issue contribution, by a process that Heim 1983a calls 'local accommodation'. Furthermore, different triggers are known to generate presuppositions with different strengths, in the sense that they may give rise to local accommodation more or less easily. Once the possibility of local accommodation is granted, it is unsurprising that its availability is constrained by pragmatic factors, and at that point the problem becomes an excessively subtle one: we need to decide whether a presupposition fails to materialize because it is not generated to begin with (possibly because of how the triggering algorithm works), or because it was generated but gave rise to local accommodation.

[9] Difficult, but not impossible to solve, as we briefly discuss in Section 7.1.

accompanying them. Strikingly, pro-speech gestures can trigger presuppositions. Tieu et al. 2019 make their point experimentally, with inferential data from three examples: one pertains to a wheel-turning, which presupposes the presence of the wheel, as in (10); one involves a person removing their glasses, hence the presupposition that the relevant person had glasses on at the relevant moment; and a third example involves a facial gesture corresponding to a person waking up, hence a presupposition that the person was previously awake.

(10) Presuppositions triggered by *TURN- WHEEL* (= 'bumper cars' condition)
    a. Simple question
    Jake and Lily are watching their four children ride bumper cars at the carnival. Each bumper car has two seats. As one of the bumper cars nears a bend in the track, the parents wonder:

    Will Sally TURN-WHEEL_ ?
    (i) Target inference: Sally is in the driver's seat.
    (ii) Control inference: Sally is in the passenger seat, not the driver's seat.

    b. Embedding under *None*
    Blake and Diane are watching their group of friends ride bumper cars at the carnival. Each bumper car has two seats. As the various bumper cars near a bend in the track, they worry that:

    None of their friends will TURN-WHEEL_ .
    (i) Target inference: Each of their friends is in the driver's seat of a bumper car
    (ii) Control inference: Not every friend is in the driver's seat of a bumper car
    (stimuli from Tieu et al. 2019, but with pictures from Schlenker, to appear)

       Experimental results suggest that both under questions and under *none*, inferences that are characteristic of presuppositions were obtained: the target inferences were significantly more endorsed than the control inferences (see Tieu et al. 2019 for details). Here too, Abrusán's algorithm as well as the one we will argue for can explain why a presupposition is generated: usually, upon acquiring the belief that *there was a wheel a x turned it*, the more stable part of the situation, namely the presence of the wheel, was antecedently believed, and thus it gets presupposed.

2.3   *Arguments from pro-speech visual animations*

Tieu et al. 2019 replicate their results with composites of written words and word-replacing visual animations ('pro-speech visual animations'). An example is displayed in (11): a visual animation depicting a change of state (from non-meditating, realized as green, to meditating, realized as blue) has the effect of presupposing the initial state; this too was assessed by way of embedding in questions, and under *none*-type quantifiers.

(11) Triggering presuppositions with visual animations (Tieu et al. 2019)
    (here: a change of state animation pertaining to an alien's antenna turning from green to blue; original video: https://youtu.be/U6dfs-XI2-4)
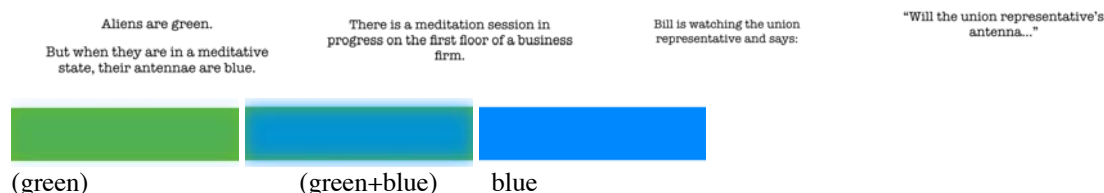
       Since people speak with gestures but not with visual animations, it is clear that this stimulus was new to the subjects, and yet they generated a presupposition 'on the fly', which highlights the need for a triggering algorithm. Since the animation represents a change of state, triggering algorithms that predict that the initial state gets presupposed can account for the observed data.

2.4 *Arguments from iconic uses of classifier predicates*

In American Sign Language (ASL), 'predicate classifiers' are lexical elements whose position or movement can be modulated in iconic ways so as to provide detailed information about the position or the path of an object. The highly iconic nature of the information conveyed by predicate classifiers has been the focus of both experimental (Emmorey and Herzig 2003) and theoretical studies (Zucchi 2011 and Davidson 2015). Taking their iconicity as a starting point, Schlenker 2019 shows that some path modulations trigger presuppositions.

Specifically, Schlenker 2019 investigates various paradigms involving the horizontal and vertical movement of a helicopter, as represented by a helicopter-denoting classifier predicate moving in signing space. Here we just provide one example and refer the reader to the original paper for several additional paradigms and broader conclusions. The consultant used a special (and possibly idiosyncratic) 2-handed form of the helicopter classifier, intended to represent a 2-rotored helicopter, as illustrated in (12). This had the advantage of triggering a presupposition that the helicopter had two rotors (Schlenker 2018 further compares the inferential strength of iconic triggers to that of lexical triggers such as *CONTINUE*).

(12) Horizontal movement of a 2-rotored helicopter classifier, transcribed as: *GO-helicopter-large* (ASL 34, 3530a)

The helicopter path involved a movement from a Boston-denoting locus to a New York-denoting locus, and the entire construction was embedded under *IF* and *MAYBE* to assess presupposition projection. The paradigm with *IF* is illustrated in (13), with quantitative acceptability judgments from the consultant on a 7-point scale, with 7 = best.[10]

(13) *Horizontal movement, IF*
Context: our company has one helicopter and one airplane.
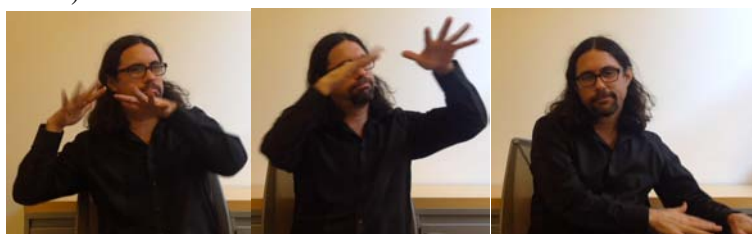WITHIN 1-HOUR OUR COMPANY BIG HELICOPTER BOSTON$_a$ NEW-YORK$_b$ **IF** a-_____-b, 2-EMAIL-1.
'If within the next hour our company's big helicopter … from Boston to New York, e-mail me.'
(ASL, 34, 3637a, d, e, f, g; 3 judgments) Video (including conditions b. and c.): http://bit.ly/2CGIYhD

Condition (ASL, 34, 3637; 3 judgments)	Words (replacing ____) and acceptability	Translation (replacing …)
a. neutral path	[7] GO-helicopter-large_	flies
b. orthogonal detour	[6.7] GO-helicopter-large__|__no_acceleration	makes an orthogonal detour on its way
c. at-issue control of orthogonal detour	[5.7] GO-helicopter-large_ WITH __|__no_acceleration	flies with an orthogonal detour on its way
d. pause in the middle	[6.7] GO-helicopter-large__ __	pauses to hover on its way
e. at-issue control of pause in the middle	[6.7] GO-helicopter-large__ WITH PAUSE __ __	flies with a pause to hover on its way

The consultant assessed the inferential strength of several inferences (also on a 7-point scale), including one to the effect that the helicopter had two rotors, and one to the effect that the trip would in fact take place. For our purposes, the main results are the following, illustrated on the case of embedding under *IF*:
(i) All conditions yielded strong endorsement (around 6.5 out of 7) of a presuppositional inference that

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[10] Our summary of the paradigm does not include a 'curved path' modulation, which didn't trigger a standard presupposition but rather a conditionalized presupposition, called 'cosupposition' in the literature on co-speech gestures; its theoretical significance is discussed in Schlenker 2019.

the helicopter has two rotors.

(ii) The condition in (13)b, which iconically displayed a path with an orthogonal detour, yielded a relatively strong (= 5) endorsement of the presuppositional inference that the movement from Boston to New York would in fact take place (though not necessarily with the detour, which was at-issue). A control expressing the same information with an explicit modifier (roughly, 'with the path shown') didn't trigger this presupposition (endorsement of the same inference was just 3.7).

(iii) The condition in (13)d, which iconically displayed a straight path with a pause in the middle to hover, also yielded a relatively strong (= 5.7) endorsement of the inference that the movement would take place (though not necessarily with a pause, as this was at-issue); here too, a control with an explicit at-issue modifier (roughly, 'with a pause like this') didn't trigger this presupposition (endorsement was just 3.3).

Thus iconic information about the shape of the helicopter triggers a presupposition. Similarly, a pause to hover or an orthogonal detour on the way from Boston to New York trigger a presupposition that the trip will take place. These are rather unusual path modifications and thus it is very unlikely that they are lexical presuppositions (in fact, it is doubtful that there is anything lexical about the iconic paths themselves). From the present perspective, the intuitive reason for these presuppositions should be as follows (although it should admittedly be assessed on independent grounds): upon learning (especially by direct experience) that a two-rotored helicopter went from Boston to New York, one is likely to have had previous information about the helicopter (which one might have seen before), but not about the trip (which might change from occasion to occasion). On the other hand, upon learning that a helicopter went from Boston to New York with an orthogonal detour or a pause in the middle, chances are that these modifications were unexpected, and thus that one antecedently knew about the overall trip but not about the path modification.[11]

3   The need for a triggering algorithm II: contextual entailments

We turn to a different class of arguments in favor of the existence of a triggering algorithm: sometimes presuppositions could not be triggered on lexical grounds because the relevant words do not lexically imply the purported presuppositions. Rather, it is only when some contextual assumptions hold that the entailments go through, and that presuppositions can arise.

3.1   Arguments from contextual triggers

One such case was briefly mentioned in Schlenker 2010, but it can be strengthened. The idea was that *x announces that p* entails that *p* in some but not all contexts: one can announce false things, but when *x announces that p* contextually entails that *p*, *p* tends to be presupposed. Schlenker 2010 contrasted *announce* with *inform*, alleging that only the latter lexically entails (and presupposes) the truth of its complement; but when contextual assumptions enforce the veridicality of *announce*, the two verbs trigger presuppositions on a par. However Anand and Hacquard 2014 correctly challenge the claim that *inform* lexically entails the truth of its complement, in part by way of attested examples in which *falsely inform* can be used without any air of contradiction:

(14) a. Family falsely informed that soldier son was killed in Afghanistan.
      b. From March 2012, Peart's and King's co-conspirators are alleged to have contacted victims in the U.S.
      and falsely informed them that they had won more than a million dollars in a lottery.
      (Anand and Hacquard 2014).

In view of Anand and Hacquard's observation, *announce* and *inform* are *both* examples of contextual triggers. Schlenker 2010 illustrates his claims with the *announce*-related sentences in (15), which are about a group of responsible 30-year olds. But the facts are clearer if *announce* is replaced with *inform*, and per Anand and Hacquard's observation, they make the same theoretical point.

(15) a. Mary hasn't (i) announced to (ii) informed her parents that she is pregnant / I doubt that Mary has
      announced to her parents that she is pregnant.

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[11] A curved path condition triggered a conditionalized presupposition (called a 'cosupposition') of the form: *if the helicopter were to go from Boston to New York, this would involve a curved path*. See Schlenker 2019 for discussion.

=> Mary is pregnant.
c. Has Mary (i) announced to (ii) informed her parents that she is pregnant?
=> Mary is pregnant.
d. None of these ten women has (i) announced to (ii) informed her parents that she is pregnant.
=> Each of these ten women is pregnant.
(Examples in (i) from Schlenker 2010)

The main suggestion in Schlenker 2010 was that *announce* (and now by extension, *inform*) tends to be presuppositional when, relative to its local context, *x announces to y that p* entails that p is true.[12] The point was made with the example in (16).

(16) At a costumed party, we encounter someone with a mask. We do not know whether this is Ann, an 11-year old, or Mary, a 30-year old.
If this is Mary, the person in front of us has / has not (i) announced to (ii) informed her parents that she is pregnant. (Schlenker 2010)

In the global context, *the person in front of us has announced to her parents that she is pregnant* certainly doesn't entail that the person in question is pregnant, since Ann, the11-year old, couldn't be. But with the addition of the *if*-clause, the local context of consequent clause ensures that the person in front of us is Mary (because the local context of the consequent of a conditional includes information that follows from the antecedent - see for instance Heim 1983a, Schlenker 2009). And relative to that local context, *the person in front of us has / has not announced to her parents that she is pregnant* behaves essentially like *Mary has / hasn't announced to her parents that she is pregnant*. The same facts seem to us to hold if *informed* replaces *announced to*.

In this case too, Abrusán 2011 as well as our own triggering rule can help explain the data. Upon acquiring the belief that *x (correctly) announced y that q*, or *x informs y that q*, one would typically have an antecedent belief about the fact described by *q* . (There will be exceptions in which one typically learns that *q* through the announcement; we revisit this issue in Sections 7.2 and 10.1.)

3.2   *Arguments from complex triggers*
A different type of argument can be provided by complex expressions which trigger presuppositions, and yet (i) do not contain lexical triggers that could be responsible for them, and (ii) in some cases, only enforce the relevant inference in the presence of some contextual assumptions.

Two examples are provided in (17). In each case, the version in (i) triggers the same kind of presupposition as the version in (ii); but (ii) plausibly involves a lexical trigger whereas (i) doesn't.

(17) a. Three duels have been organized.
A: What just happened?
B: None of these six guys (i) pulled the trigger (ii) shot.
=> each still has a loaded gun
b. At a euthanasia clinic:
A: What just happened?
B: None of our three patients' executors (i) pressed the 'die' button (ii) started the process.
=> all three patients are alive

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[12] Anand and Hacquard 2014 discuss further verbs of the *inform* class, illustrated in (i).

(i) Does the book {acknowledge, admit, confirm} that Mary is the murderer?

They suggest that these verbs refer to "discourse moves which lead to the acceptance of the complement *p* into the common ground of the reported discourse", and they propose that "this acceptance of *p* can easily bleed into the actual common ground (...): an illusion of factivity arises whenever a reported context is taken to faithfully represent the conversational community in the world of evaluation." This line of analysis raises two questions. First, why do verbs of this class yield a presupposition that that the complement is true relative to the original conversation? Second, why does that presupposition get 'imported' into the reporting conversation? No general account is offered yet. In addition, this line of explanation won't extend to presuppositions that are triggered outside of speech reports, unlike the one we develop in this piece.

Pull the trigger doesn't contain a word that could generate the presupposition that the gun is loaded. In the general case, this fact isn't even entailed: one can perfectly well pull the trigger of an unloaded gun (hence no contradiction in: *Sam pulled the trigger of an unloaded gun*). But in the present situation, there is plausibly a contextual equivalence between *pull the trigger* and *shoot*, and at this point *pull the trigger* acquires the same presuppositional behavior as *shoot*. The same argument carries over to *press the 'die' button* vs. *start the process*: one can press buttons without consequences, but in the present situation there is a contextual equivalence between the relevant expressions, and the complex expressions acquire a presuppositional behavior.

Each case makes sense in view of the triggering rule we sketched at the outset: upon learning that in a duel situation someone pulled the trigger (and thus shot), one would typically antecedently know that the gun was loaded; upon learning that someone pressed the 'die' button, one would typically antecedently know that the message hadn't been sent yet or that the person was still alive.

Related observations can be made on the basis of complex expressions that are not paraphrases of any standard triggers, but still appear to trigger (possibly weak) presupposition-like inferences. Intuitively, such cases arise when an entailment is an epistemic precondition of the global informational content of an expression, as the present analysis leads one to expect. In (18), *x walked on the moon* appears to trigger the presupposition that *x is an astronaut*.

(18) a. Smith has walked on the moon.
 => Smith is an astronaut.
 b. Has Smith walked on the moon?
 => Smith is an astronaut.
 c. Smith hasn't walked on the moon.
 => Smith is an astronaut.
 d. None of these ten guys has walked on the moon.
 => Each of these ten guys is an astronaut.
 e. If Smith walked on the moon, he would be happy.
 =>? Smith is an astronaut.

Intuitively, being an astronaut is a precondition for walking on the moon. The probabilistic recipe we provided at the outset can capture this intuition: if one learns that at t Smith walked on the moon, there is a high probability that one antecedently knew that (around t) Smith was an astronaut. When this probability is sufficiently high, we should treat *Smith is an astronaut* as a presupposition of *Smith walks on the moon*.

3.3 Presupposed implicatures

Kadmon 2001 argued that some conversational implicatures are presuppositions as well, and she provides various projection tests for the inferences in (19)-(20) (Kadmon 2001 p. 214).

(19) a. Sue promised John an official invitation.
 b. Sue didn't promise John an official invitation.
 c. Maybe Sue promised John an official invitation.
 d. Did Sue promise John an official invitation?
 (a)-(d) => John wanted an official invitation

(20) A: I have to pay my water bill.
 a. B: There is a post office around the corner.
 b. B: There isn't a post office anywhere around here.
 c. B: Is there a post office around here?
 d. B: If there is a post office nearby, I'll be going there anyway.
 (a)-(d) => water bills can be paid at post offices

In each case, the inference of the a. sentence is defeasible and thus is not a lexical entailment nor a lexical presupposition.[14] Kadmon takes these inferences to be relevance implicatures, i.e. one's best

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[14] Kadmon also discusses counterfactuality inferences triggered by subjunctive conditionals, but their source is complex enough that we prefer to stay away from this topic in the present discussion (see for instance Ippolito 2003 and Schlenker 2004 for discussion). More importantly, she discusses the inferences in (i), which our analysis cannot straightforwardly derive; we revisit this point in fn. 39.

guess as to why the elementary clause would be a relevant thing to say.[15] What is striking is that these implicatures project like presuppositions. Why should this be the case? Intuitively, upon learning that Sue promised John an official invitation, one would typically antecedently know that John wanted an official invitation: here the implicature is plausibly an epistemic precondition of the target construction. In Section 6.1, we will make this reasoning more precise and will extend it to (20).

3.4   Interim summary

At this point, we have seen two classes of argument in favor of a triggering algorithm. One class has to do with rule-governed behavior: (i) Within or across languages, different words that convey the same information appear to divide it in similar ways among the at-issue and presuppositional components. (ii) Presuppositions can be generated on the basis of new gestures and visual animations for which there couldn't be a lexical form to encode the presupposition. (iii) The same conclusion holds of shape- and path-related inferences of highly iconic predicate classifiers in ASL. Another class of arguments is based on normal expressions that trigger presuppositions but couldn't do so on lexical grounds because (iv) the inference only arises in the presence of some contextual assumptions, and/or (v) the trigger is complex and does not contain words that could be responsible for the relevant presupposition. In addition, (vi) Kadmon discusses examples in which some relevance implicatures are presupposed.

We conclude that, in at least some cases, a triggering algorithm is called for. While this is consistent with the view that some presuppositions are lexically encoded while others are productively derived, we will seek to develop a relatively uniform triggering rule for all cases.[16]

4   Theories and challenges

While there have been numerous insightful but informal discussions of how presuppositions are generated (e.g. Grice 1981, Stalnaker 1974, Abbott 2000, Simons 2003), formal proposals have been of three main types (see Abrusán 2011 for an enlightening critical discussion). One class takes some presuppositional expressions to evoke some alternatives, just like scalar terms do (Abusch 2002, 2010, Chemla 2010, Schlenker 2010, Romoli 2014). Among these theories, some take presuppositions to just be scalar implicatures (Romoli 2014), others take them to deal with alternatives in special ways (Chemla 2010, Schlenker 2010), and still others start from pragmatic constraints on focus alternatives (Abusch 2002, 2010). As we will see on the example of Abusch's theory, these analyses are interesting but not predictive in the absence of an algorithm to determine which alternatives are considered (a point made very clear in Abusch's own work). A second line of investigation, developed in Simons et al. 2010 and Tonhauser et al. 2013, starts from the notion of a 'Question Under Discussion', and takes certain entailments to 'project' and thus to behave as if they were presupposed when they fail to address the Question Under Discussion; we will see that these proposals are insufficiently predictive as things stand. A third line, due to Abrusán 2011, focuses specifically on presuppositions triggered by verbal constructions, and takes those entailments of a sentence that are not about the main event to end up being presupposed; as we will see, this important proposal still faces serious empirical problems, and doesn't generalize to other triggers.

4.1   Abusch 2002, 2010

One can take Abusch's (2002, 2010) starting point to be the observation that focus can yield

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(i)   a. It is not true that Sue cried before she finished her thesis.
           b. It is quite likely that Sue cried before she finished her thesis.
           c. Did Sue cry before she finished her thesis?
           a, b, c => Sue finished her thesis

[15] While (19) might conceivably involve a contextual entailment rather than an implicature, (20) genuinely seems to involve a relevance implicature: it is because of discourse situation (and assumption of relevance) that utterance that B's reply triggers the inference that water bills can be paid at post offices.

[16] We write 'relatively' rather than 'completely' because we will treat cases of referential failure as triggering a special sort of presupposition, although it will interact with the normal algorithm to yield the desired results.

presupposition-like phenomena.[17] For instance, (21) may evoke the set of alternatives {You will vote for Obama in November, you will vote for McCain in November}. With the assumption that at least one of these alternatives is true, we obtain the inference that you will in fact vote in November.

(21) Will you vote for [Obama]$_F$ in November?
       => you will vote in November

By assuming that the items in (22) lexically activate appropriately-defined scales, Abusch can derive their presuppositional behavior.

(22) a. stop: {stop, continue}
       b. win: {win, lose}
       c. be right: {be right, be wrong}
       d. be aware: {be aware, be unaware}

Here all expressions are taken to have a bivalent meaning, but it is presupposed that one of the alternatives is true, hence the desired presuppositional effect. This is particularly easy to see with the semantic decomposition offered in (23)a,b for *x stops smoking* and *x continues smoking*: it is immediate that their disjunction that is equivalent to *x smoked*, i.e. their joint presupposition.

(23) a. x stops smoking   = x smoked and x doesn't smoke
       b. x continues smoking = x smoked and x smokes
       c. (x stops smoking or x continues smoking) <=> x smoked

The immediate difficulty is that with different alternatives, different results are obtained. In (24), *continue* is given the set of alternatives {continue, start}, and as a result *x continues smoking* presupposes their disjunction, namely that *x smokes*. While this reading may be accessed in special contexts, one needs to explain why in general the presupposition is instead that *x smoked*, while it is *asserted* that *x still smokes*.[18]

(24) Deviant alternative set: continue: {continue, start}
       a. x starts smoking   = x didn't smoke and x smokes
       b. x continues smoking = x smoked and x smokes
       c. (x starts smoking or x continues smoking) <=> x smokes

In Abusch's defense, there seems to be genuine arbitrariness in some cases. She mentions the exquisite contrast between *x is aware that p* and *x is right that p:* both have a believing/saying component, and veridical component, but *x is aware that p* presupposes that *p* is true and asserts that *x believes p*, whereas *x is right that p* presupposes that *x said/believes that p* and asserts that *p* is true. The contrast naturally follows from Abusch's alternatives in (22)c,d: *aware* and *unaware* both a veridical component, hence their disjunction does too; *be right* and *be wrong* both have a 'believing/saying' component, hence it too is preserved by their disjunction. But the lexical nature of the account seems to be essential to derive this fine-grained contrast, since there is no obvious difference between the global meaning of *be aware* and *be right*. We will argue in Section 6.2 that on closer inspection, our account might derive this contrast from fine-grained lexical differences between the two cases.

4.2   *Simons et al. 2010*

For their part, Simon et al. 2010 start from the (very convincing) observation that 'Questions under Discussion' (QUDs) may affect whether a presupposition arises or not. For instance, in (25) the QUD is whether France has a king, and a result the definite description fails to presuppose that there is king, as it would be bad conversational practice to presuppose what's under discussion.

(25) –Does France have a king?
       –Well, the king of France didn't attend the opening of Parliament.

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[17] See for instance Büring 2012 for a far more detailed discussion of the inferential effects of focus and givenness, which we do not discuss in the present paper.

[18] Special contexts involve contrastive focus, as in *Did Robin start smoking or did Robin continue to smoke?* The fact that alternative can change presuppositions when manipulated is of course consonant with Abusch's theory, but it also highlights the need for certain lexical stipulations – as Abusch herself makes transparently clear.

This fact alone can be derived by every theory that allows for local accommodation. Simons et al. go much further in suggesting that entailments may 'project' beyond operators, and may thus behave like presuppositions, in case they are not relevant to the QUD, thanks to the definitions in (26):

(26) Definition of relevance and at-issueness in Simons et al. 2010
      a. An assertion is relevant to a QUD iff it contextually entails a partial or complete answer to the QUD.
      b. A question is relevant to a QUD iff it has an answer that contextually entails a partial/ complete answer to the QUD.
      c. A proposition p is at-issue relative to a question Q iff the question ?p is relevant to Q.

To illustrate, in (27) we initially treat *know* as bivalent and veridical (it entails the truth of its complement) and note that the entailment *you can eat raw vegetables* is not relevant to the QUD, and thus it is not at-issue and projects; things are different with the entailment that France has a king in (25).

(27) Background scenario: a nutritionist has been visiting first grade classrooms to talk to the children about healthy eating
      Q: What most surprised you about the first graders?
      A: They didn't know that you can eat raw vegetables.

The difficulty, noted in Chemla 2006, is that this account is insufficiently predictive and/or makes impossible predictions. Suppose *p* provides an answer to Q, and take *p'* to be an entailment of *p* (*p'* could be identical to *p*, as in the case illustrated in (28)). Find a proposition *A* that partly overlaps with every cell of Q (so that *not A* also overlaps with every cell of Q). For instance, take a 2-cell QUD similar to (25), *Does Spain have a king?*, with a simple answer, *p = Spain has a king* (which does not trigger a presupposition). Take *A* to be: *Spain has the best cheese in the world*. This certainly overlaps with each of the two cells. Take an entailment *p'* of *p*, either *p* itself, or something weaker, for instance *Spain has a monarch*. Now *p'* has *(p' or A)* as an entailment, and it is not relevant to Q, so *(p' or A)* can project. Similarly, *(p' or not A)* can project. If both do, then we get a presupposition that *p'*: it now becomes presupposed that Spain has a monarch. In fact, every entailment *p'* of *p* is predicted to project – which couldn't be correct, and calls, at a minimum, for some constraints.

(28) An answer p to a QUD ?q

On the assumption that this account can be constrained, it still encounters another problem, discussed by Abrusán 2011 (and noted by the authors themselves). Abrusán notes that the account incorrectly predicts that presuppositions should fail to be generated in (29) and (30), since the fact that the first graders failed the exam, or that John used to smoke, are relevant to the QUD; but intuitively the presuppositions are generated in this case.

(29) Q: What most surprised you about the first graders?
      A: They didn't know that they have failed the exam.

(30) Q: What do you know about John?
      B: He still didn't quit smoking.

4.3   Abrusán 2011

4.3.1   Insights

After criticizing Abusch's and Simons et al.'s accounts, Abrusán 2011 proposes a triggering algorithm for the verbal case. For her, entailments that are not 'about' the event time of the verb get presupposed (this is motivated by considerations on attention, as only entailments that are about the event time are taken to be the main point of such constructions). We won't be concerned with how 'aboutness' is

defined.[19] In the case of change of state verbs, which will be of some importance below, Abrusán's theory works as in (31).

(31) a. John stopped smoking at t_1.
      b. Entailment 1: John does not smoke at t_2
      c. Entailment 2: John smoked at t_2 (where t_2 is some contextually given interval before t_1)

The simplified representation in (31)a, with event time t_1, comes with several entailments, two of which are stated in (31)b,c. Entailment 1 is about event time t_1 and thus it does not get presupposed. By contrast, Entailment 2 is not about event time t_1 and thus it gets presupposed.

Our analysis will agree with Abrusán's in some but not in all cases. Take for instance change of state verbs. For Abrusán, *John stopped smoking at t_1* triggers a presupposition that John smoked before t_1 because this entailment is not about the matrix event time. For us, the intuition is a bit different: upon learning that John doesn't smoke at t_1 but did before, one would typically antecedently know the part about the past, namely that John smoked before t_1. We discuss two types of counterexamples to Abrusán's theory. The main problem is that her analysis overgenerates because it treats as presupposed some entailments which are not. From our perspective, this happens when an entailment *p* of an expression *pp'* is not about the matrix event time (hence Abrusán predicts a presupposition), and yet when one learns that *pp'*, one doesn't typically antecedently know that *p* (so the present analysis predicts no presupposition). In other cases, Abrusán's theory undergenerates, because an entailment *p* of an expression *pp'* is about the matrix event time (hence it is at-issue for Abrusán), and yet when one learns that *pp'*, one typically antecedently knows that *p*.

4.3.2   Overgeneration

As mentioned by N. Klinedinst (p.c.), a class of verbs discussed in Anand and Hacquard 2014 present systematic exceptions to Abrusán's analysis, as illustrated in (32) (*establish* could be added to the class, as noted by Klinedinst):

(32) a. The bloody gloves {demonstrate, imply, prove, show} that Mary committed the murder.
      => Mary committed the murder.
      b. Do the bloody gloves {demonstrate, imply, prove, show} that Mary committed the murder?
      ≠> Mary committed the murder.
      (modified from Anand and Hacquard 2014)

It is immediate that the entailment about the past murder is not about the matrix event time of the construction and is thus predicted by Abrusán to be presupposed, contrary to fact. Anand and Hacquard note that the entailment might not be lexical, as in the examples in (33), which need not come with a veridical entailment. But in view of the cases discussed above in which contextual entailment is enough to trigger presuppositions, it is dubious that this explains why no presuppositions are triggered when the entailments do go through.

(33) The bloody gloves {demonstrate, imply, prove, show} to John that Mary committed the murder.
      (modified from Anand and Hacquard 2014)

From the present perspective, when one learns that *x demonstrates* (or: *implies, proves, shows, establishes*) *that p, p* is often hard/non-trivial, and thus that one does *not* antecedently know that *p*; one might learn *p by* learning that x demonstrates it. Thus we do not expect *p* to count as an epistemic precondition of *x demonstrates that p*. The same analysis extends to (6)b (= *PULL-GUN-SHOOT*), which is another case of overgeneration: here the initial state (= the gun's presence under the jacket) is predicted to be presupposed but isn't, because upon learning that someone pulls a gun from his jacket and shoots, one typically doesn't antecedently know that the person has a gun.

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[19] In a nutshell, a sentence S is *not* about an individual [named by] c just in case for every interpretation M, S is true in M iff for every interpretation M' which is just like M for atomic sentences, except possibly ones that contain c, S is true in M'. Abrusán 2011 discusses various necessary refinements to obtain a theory of presupposition generation. In particular, she needs to treat the matrix and the embedded time arguments in *John knows (at t_1) that it is raining (at t_1)* as counting as different so as to differentiate between entailments that should vs. shouldn't become presupposed).

Further problems arise when we consider presuppositions triggered from contextual entailments. Take *x is pregnant* and *x is a doctor*: in both cases, common sense knowledge yields entailments that something relevant happened before the matrix event time: *x was impregnated at least 5 days ago, x went to medical school*. With a context-sensitive version of Abrusán's algorithm, these entailments are predicted to be presupposed, but in fact neither is. From our perspective, this is because neither is an epistemic precondition of the target proposition: upon learning that *x is pregnant*, one typically does not antecedently know that *x was impregnated at least 5 days ago;* similarly, when one learns that *x is a doctor*, one typically does not antecedently know that *x went to medical school;* rather, it is *by* learning that *x is a doctor* that one acquires the belief that *x went to medical school*.

(34) a. Mary is pregnant. => Mary was impregnated at least 5 days ago
      b. Is Mary pregnant? ≠> Mary was impregnated at least 5 days ago

(35) a. Mary is a doctor. => Mary went to medical school
      b. Is Mary a doctor? ≠> Mary went to medical school

Abrusán's theory correctly predicts that in change of state constructions, the initial state gets presupposed, as we illustrated at the outset in (8). But what about the final state? She argues that, as a matter of lexical fact, such inferences are pragmatic rather than lexical.[20] But once the possibility of contextually triggered presuppositions is taken into account, it becomes harder to explain why future entailments are not presupposed. Even on the assumption that lexical entailments get presupposed 'first', it's not always clear what would go wrong with a presupposition that the final state will be reached. Take the sentence *Will the police blow up this suspicious package?* Certainly, *x blows up y* contextually entails that, at a later point, y is destroyed. Furthermore, such a presupposition wouldn't make the question idle – it would in effect be asking about the manner of destruction. But this is not how the question is understood: the final state just isn't presupposed.[21] From the present perspective, the asymmetry between initial and final states is relatively expected: upon learning that x blows up y, one typically has greater antecedent knowledge of the past than of the future (we revisit this asymmetry in Section 7.1).[22]

4.3.3 Undergeneration

There are also cases in which Abrusán's theory arguably undergenerates, and treats as at-issue some entailments that are in fact presupposed. One such case is discussed by Abrusán 2011: it pertains to *regret*. (36)a triggers the inference that John believes that he worked as a linguist (this might come in addition to a factive presupposition to the effect that John in fact worked as a linguist[23]). But this inference pertains to the matrix event time, so without a refinement, Abrusán's theory predicts that it

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[20] Abrusán argues that the contrast between (ia) and (ib) suggests that *smoked before* is entailed but *didn't smoke after* isn't. But (ib) leaves open the possibility that there was a small interval between the stop and the new start. (ii) is thus a better test: Abrusán expects (maybe correctly) that (ii)b should be more acceptable than (ii)a.

(i)   a. #John stopped smoking, but he has never smoked before.
         b. John stopped smoking, but then he started again.

(ii)   a. #(At 12:05pm sharp,) the temperature stopped being negative, but was never negative before.
         b. (At 12:05pm sharp,) the temperature stopped being negative, but was never non-negative after.

[21] The same point could be made with the verbal gesture $TAKE\text{-}OFF\text{-}ROTATING$, used in Schlenker, to appear to represent a helicopter take off. There is certainly a contextual entailment that the helicopter will end up in the air, but it is not presupposed: *At 12:05, will the company's helicopter* $TAKE\text{-}OFF\text{-}ROTATING$? definitely doesn't presuppose that shortly after 12:05 the helicopter will be in the air.

[22] We believe that there are also cases of undergeneration with Abrusán's theory.

[23] We write that the factive presupposition *might* come in addition to the belief presupposition because an alternative possibility is that it derives from it. In a nutshell, many modalized presuppositions become factive when their modal character is not explicitly justified (this is known as the 'Proviso Problem', discussed for instance in Geurts 1999, Singh 2007, Schlenker 2011, Lassiter 2012). This arises for instance with *want*: out of the blue, *Ann doesn't want me to stop smoking* triggers the inference that I smoked before; but when the target sentence is preceded by *Ann wrongly believes that I am a smoker, and __* , the factive inference disappears.

should not be presupposed, contrary to fact.

(36) a. Does John regret that he worked as a linguist?
       b. => John believes that he worked as a linguist

Abrusán 2011 proposes such a refinement. For her, when there is such an entailment, it is not about the matrix event time, but about a time right before, so that this entailment can be presupposed; pragmatic reasoning then leads to the inference that the entailment still held at the matrix event time.

But an analysis based on pragmatic enrichment does not seem right: in a situation in which a person's beliefs keep changing because of memory problems, *x regrets that p* still comes with the presupposition that *x believes that p*, not with the (contextually plausible) presupposition that *x believed that p:*

(37) John has Alzheimer's and spends his time forgetting about his past career in linguistics.
       Does John regret that he worked as a semanticist?
       => John believes that he worked as a semanticist

In (37), the lexical part of Abrusán's analysis of *regret* predicts that right before the time of utterance John believed that he had been a semanticist. There is no pragmatic reason to strengthen this inference to encompass the time of utterance, since John keeps forgetting. But the inference still goes through, which suggests that it is lexically triggered by *regret*.[24]

From the present perspective, can we explain why *x regrets that p* doesn't just entail but in fact presupposes that *x believes p*? The question is as follows: on the assumption that one has learned that *x believes that p and x regrets that p,* is it usually the case that one antecedently knows that *x believes that p*? This seems plausible on the assumption that one usually knows more about a person's beliefs than about their desires. This makes sense in view of the fact that a person's beliefs can be inferred from the information they have access to, in particular the state of the world, whereas their desires are more complex to infer. This would need to be explored in greater detail, but in any event there is nothing in the present theory to block presupposition generation in this case, unlike in Abrusán's theory.

We believe that there are further cases of undergeneration in Abrusán's theory. *At t, x deters y from q-ing* presupposes that at t y tried to q. For instance, *In 2016, did the Obama administration deter Russia from influencing the election?* presupposes that in 2016 Russia tried to influence the election; it isn't clear how the strategies deployed by Abrusán for *regret* will work in this case.[25]

In sum, there are systematic cases in which Abrusán's system overgenerates, and these can in principle be avoided by the present theory; there also seem to be cases of undergeneration, which seem easier to avoid within the present framework.

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[24] Let us add that Abrusán 2011 (complemented by Abrusán 2019) considers another possibility, namely that *x regrets that p* only presupposes p, but not *x believes that p*; however the attitudinal inference is due to a mechanism of perspectival shift. As things stand, it's unclear how this mechanism will derive all the necessary presuppositional data, especially in quantified contexts, as in 0: universal projection of a factive presupposition just yields that *each of my students flunked the exam,* but it's not clear how perspectival shift interacts with this to yield that all think they flunked.

(i) None of my students regrets that he flunked the exam.
=> Each of my students believes that he flunked the exam

[25] Let us add that some of our ASL data pertaining to classifier predicates are also hard to capture within Abrusán's system. As we saw in (13)b,d, an iconic construction representing a helicopter take-off can be realized with an orthogonal detour or with a pause to hover in the middle. In such cases, what is at-issue is that there will be such a detour or pause, and it tends to get presupposed that the take-off will take place. With other movement modifications, this presupposition does not arise. On the face of it, it would seem that the fact that the take-off takes place *is* about the matrix event time, which would lead one to expect, on Abrusán's theory, that this cannot be presupposed. (While this has not been tested, it is possible that when one adds a temporal modifier, such *in 54 seconds,* one might understand that it provides information about the time of the detour or the time of the hovering. If so, Abrusán could argue that despite initial appearances the matrix event time is the time of the detour or of the hovering. But this would still beg the question of the direction of causality: in view of the presuppositional nature of the rest of the expression, one might expect that the modifier targets the at-issue part of the meaning anyway.)

5   Proposal: presuppositions as epistemic preconditions

We turn to a more precise statement of our proposal. We state the triggering rule in the propositional case, we illustrate it with a simple formal example, we extend it to non-propositional cases, and finally we explain how it interacts with the context. In a nutshell, we posit that presuppositions are generated relative to different contexts, with a preference for (i) the most general one whenever possible, and (ii) the smallest syntactic units whenever possible.

It might help to consider again our driving intuition, which is that entailments that are cognitively inert in cognitive life should be semantically inert (= trivial) in their linguistic environment. Take our initial example in (2)a. Suppose you are in a room, and see at time t that x is unscrewing a bulb from the ceiling, corresponding to the content of *UNSCREW-ceiling*. This entails that the bulb is on the ceiling, and that it is being unscrewed. But it's unlikely that you learned everything at once at t; rather, stable properties of the situation, and in particular the fact that the bulb is on the ceiling, are probably things you knew at time t-1. There will be exceptions to this, as when you enter a room and simultaneously see that a bulb is on the ceiling and that someone is unscrewing it. But these exceptions will be comparatively rare. Those entailments that you are likely to have known at t-1 will the presuppositions of this proposition.

5.1   Propositional case

We will consider the meaning of an expression E relative to a context c', and we will sometimes write E as pp' if its meaning is equivalent, relative to the local context c' of E, to the conjunction of p and p' (i.e. c' $\models$ E $\Leftrightarrow$ (p and p')). This will have the advantage that we can graphically identify entailments of interest, for instance in case p is the observed presupposition. But this notation is for convenience only, as will never need to stipulate a division of E into p and p': which entailments end up treated as presuppositions follows from the triggering rule.

We work with discrete times, and write $acquire_t\ pp'$ if the relevant individual or individuals (i) did not have the belief that p *and* p' before t, and (ii) have that belief at t. In other words, their beliefs changed between t-1 and t, but this leaves open whether they already believed that p, or that p', or neither, at time t-1. We will write $believe_{t-1}\ p$ in case the relevant individual(s) already believed that p at time t-1.

Now our presupposition triggering rule for the propositional case can be stated as follows:

(38)   **Presupposition triggering relative to a context (propositional case)**
For some probability threshold a, for a propositional expression E in context c', for random time variables t and t', trigger a presupposition p if:
(i) c' $\models$ E => p[26], and
(ii) $P(believe_{t-1}\ \mathbf{p}\ |\ believe_{t-1}\ c'\ \&\ acquire_t\ \mathbf{E}) \geq a$

where P ($\bullet$ | _) is the subjective conditional probability of $\bullet$ given _ and $\mathbf{E}$ and $\mathbf{p}$ are the semantic values of E and p respectively (when no confusion arises, we will forego boldfacing).

Several points needs to be clarified at the outset.
• We take the relevant notion of probability to be a subjective probability that a generic agent could have in view of the information contained in the local context c'.
• In local context theory (e.g. Schlenker 2009), the local context c' of a propositional expression pp' is itself propositional, which is crucial to ensure that c' can entail the presupposition (e.g. p if p is the presupposition of pp'). This also means one can believe c'.
• The agent of the belief is taken to be a generic agent, and thus the crucial test can be paraphrased as: *upon acquiring the belief that pp' relative to beliefs c', what is the probability that one antecedently believed p?*[27]

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[26] In simple cases, condition (i) might or might not be redundant: if p isn't a contextual entailment of E relative to c', one might think it unlikely that p is an epistemic precondition of E. But as nothing enforces this in the general case, we state explicitly that only contextual entailments are candidates for presuppositions. We revisit this point in fn. 63.

[27] If one wishes to use this as a linguistic test, it is wise to state pp' in a presupposition-neutral fashion, e.g. as *Sam correctly believes that it's raining* rather than *Sam knows that it's raining*.

• We may take as primitive the notion of an agent believing a proposition. But to be concrete, we can also analyze it further in standard model-theoretic terms*: x believe$_t$ **p** holds just in case each world/context compatible with what x believes at t makes the proposition **p** true (we say world/context because one may choose more or less fine-grained notions depending on one's goals, with the standard assumption that contexts are more fine-grained than worlds; in some extensions, such as those involving anaphora in Section 9, the context will have to contain an assignment function so as to assign values to variables).

• We take as primitive the probability of open sentences, but these can be derived, as discussed by Lassiter 2011 and Hughes 1962. For instance, if there are two helicopters h$_1$ and h$_2$, and one has an equal chance of encountering each, while h$_1$ has a 10% chance of taking off while h$_2$ has a 2% of taking off, the probability of *x is a helicopter and x takes off* is 1/2 • 10% + 1/2 • 2% = 11%. If there is a single helicopter *h* and only two times t and t+1, and one has an equal chance of encountering each, with a 10% chance of take-off at t$_1$ and a 2% chance at t$_2$, the probability of the open sentence *h takes off at t* (where *h* is a constant and *t* is a variable) will again be 1/2 • 10% + 1/2 • 2% = 11%. Hughes's more general derivation of the probabilities of open sentences is summarized in Appendix I (we make crucial use of conditional probabilities of the form *P(A(t-1, …) | B(t-1, t, …))*, in accordance with the format of (38)(ii), where *A* and *B* are complex formulas making reference to beliefs in certain propositions).

• When we consider propositions with explicit time dependency, such as *at t' x unscrews a bulb from the ceiling*, it will make sense to have in one way or another an over-representation of discovery times that correspond to the event time, consonant with the idea that we learn many things through direct perception, and thus at the event time. Thus when we compute *P(believe$_{t-1}$ at t' there is a bulb on the ceiling | believe$_{t-1}$ c' & acquire$_t$ at t' x unscrews a bulb from the ceiling)*, cases t = t' will be overrepresented.[28]

     We come back below to a generalization of the rule to expressions of a type that 'ends in t', in particular to predicative expressions (this dovetails with the definition of local contexts in Schlenker 2009, which also applies to various expressions of a type that 'ends in t'), after which we will discuss the choice of the context c' relative to which contextual entailment is assessed. Before doing so, however, we provide a schematic illustration of how the analysis works.

5.2   Formal illustration

We illustrate the workings of the basic proposal in a very simple case in which the context c' is made of 3 worlds, with c' = {w$_1$, w$_2$, w$_3$}. Now we assume that the contextual meaning of E relative to c' is just {w$_1$}, and we ask which entailments of *E* relative to c' ought to be treated as presuppositions. To make this decision, we need to proceed as follows.

Step 1. We consider all the possible entailments of *E* relative to c'. These all the subsets of c' which include {w$_1$}. To simplify notations, we graphically identify sets of worlds with sequences of worlds, and hence we write *w$_1$* for {*w$_1$*}, *w$_1$w$_2$* for {*w$_1$, w$_2$*}, etc. We thus we have the following:

(39) Subsets of c' that include {w$_1$}, written as sequences of the worlds they contain

$$w_1w_2 \quad\quad \begin{matrix} w_1w_2w_3 \\ \\ w_1 \end{matrix} \quad w_1w_3$$

Each of these entailments could in principle be selected to become a presupposition of the local meaning of *E* relative to c', namely {w$_1$}.

Step 2. To decide which entailments, if any, should be presupposed, we need to consider the probability that when at time t the relevant belief becomes {w$_1$}, the entailment is already believed at t-1.

     We assume that belief grows in a monotonic fashion, i.e. can only remain constant or become more specific with time. Since {w$_1$} is believed at t, possible beliefs to consider at t-1 should include {w$_1$}. In the case at hand, let us restrict attention to the case in which prior beliefs were constrained by

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[28] As discussed in Appendix I, this may simply be because there are virtually no cases of such discoveries in which the discovery fails to happen at the even time. Alternatively, we can follow Leblanc's procedure and give disproportionate weight to tuples <t-1, t, … , t', … > for which t = t'.

(i.e. were at least as specific as) c'. This leaves us again with three entailments represented above w_1 in (39) (we don't need to consider w_1 itself because by assumption this belief was *acquired* at t, hence was not present at t-1). But we need to consider each potential belief state. In particular, the probability that the earlier belief state was $w_1 w_2 w_3$ cannot, without further specification, be computed from the probability that it was $w_1 w_2$ and the probability that it was $w_2 w_3$. For instance, in case $w_1 w_2 w_3$ is the entire set of possible worlds, we might know for a fact that the relevant agent knew *something*, making the trivial belief state one that was held with probability 0. But of course this doesn't imply that the probability that the earlier belief was $w_1 w_2$ is zero, or that the probability that the earlier belief was $w_1 w_3$ is zero.

With mnemonic notations, we associate to the three possible belief states the probabilities p_{12}, p_{13}, p_{123}, which gives rise to the following situation:

(40) Subsets of c' that include $\{w_1\}$, with numbers corresponding to the probability that they were the relevant agent's belief at t-1

$$w_1 w_2 w_3$$
$$p_{123}$$

$$w_1 w_2 \qquad\qquad\qquad w_1 w_3$$
$$p_{12} \qquad\qquad\qquad p_{13}$$
$$w_1$$

Since by assumption these are all the possible belief states, and the belief $\{w_1\}$ was *acquired* at t (and hence didn't follow from the belief state at t-1), the three probabilities we have here must sum to 1:

(41) $p_{12} + p_{13} + p_{123} = 1$

To illustrate, we can think of *E* as *Robin stopped smoking*, i.e. *Robin smoked and doesn't smoke*, whose value is $\{w_1\}$ (in abbreviated notation, w). We can think of $w_1 w_2$ as the value of *Robin smoked*, and of $w_1 w_3$ as the value of *Robin doesn't smoke*. As a result, $w_1 w_2 w_3$ is the value of the disjunction *Robin smoked or Robin doesn't smoke*. If it is taken to be impossible that the prior belief state was this disjunction, it should be assigned probability 0.

Let us seek to determine the probability that the earlier belief state entailed that Robin smoked before. This is just p_{12}. The probability that the earlier belief state entailed that Robin doesn't now smoke is p_{13}. The probability that the earlier belief entailed that Robin smoked or doesn't smoke is the sum $p_{12} + p_{13} + p_{123} = 1$.

Now if we set the threshold for treating an entailment as a presupposition at .8 (i.e. 80% chance of antecedent belief in the purported presupposition), we get the following possible cases.

(42) What gets presupposed for a threshold of a = .8

a. $p_{12} = .8$, $p_{13} = .2$ $p_{123} = 0$
=> $w_1 w_2$ and $w_1 w_2 w_3$ both get presupposed, but the strongest entailment (i.e. their conjunction) is $w_1 w_2$, which is what we perceive as 'the' presupposition of the sentence

b. $p_{12} = .7$, $p_{13} = .2$ $p_{123} = .1$
Neither $w_1 w_2$ nor $w_1 w_3$ gets presupposed, and only the weaker entailment $w_1 w_2 w_3$ gets presupposed.

c. $p_{12} = 0$, $p_{13} = .9$ $p_{123} = .1$
Now $w_1 w_3$ and of course $w_1 w_2 w_3$ get presupposed, but the strongest entailment is $w_1 w_3$, which is what we perceive as 'the' presupposition of the sentence

Importantly, since we assumed that the context of evaluation is c' = $w_1 w_2 w_3$, a presupposition that $w_1 w_2 w_3$ won't be perceived, as it will be entirely redundant with the context.[29]

The upshot at this point is that we do not need to pre-define entailments that are candidates to be turned into presuppositions. Our triggering rule considers them all. Propositions that are already entailed by the context are always 'presupposed', but their effects are not felt. Entailments that do become presupposed while making their effects felt depend on the analysis of the discovery process, i.e. the probability that they will already be known when the crucial new belief is acquired.

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[29] If necessary, one could define presuppositions generated by *E* relative to c' to be those contextual entailments of *E* that have a high chance of being antecedently believed, *minus* the entailments of c'. We see no need for this measure at this point.

5.3 Extended proposal: expressions whose type 'ends in t'

We now extend the proposal to expressions E whose type 'ends in t', notably predicates. Some adjustments are needed. First, we must follow Schlenker 2009 in treating the contexts of E to be of the same type as E, and entailment to be generalized entailment.[30] Second, we must feed arguments to p and E to obtain propositions that can be believed. This requires making use of variables over individual.

(43) **Triggering rule**
For a certain probability threshold a, for an expression E whose type 'ends in t', trigger a presupposition p with respect to context c' if:

(i) c' $\models$ E => p, and
(ii) $P(\text{believe}_{t-1}\ \mathbf{p}(x_1) \dots (x_n)\ |\ \text{believe}_{t-1}\ c'(x_1) \dots (x_n)\ \&\ \text{acquire}_t\ \mathbf{E}(x_1) \dots (x_n)) \geq a$

where P ($\bullet$ | _) is the subjective conditional probability of $\bullet$ given _, $\mathbf{E}$ and $\mathbf{p}$ are the semantic values of E and p respectively, and $x_1 \dots x_n$ are random variables ranging over objects of the appropriate types to yield a truth value when given as arguments to $\mathbf{E}$ and c'.

One further adjustment is called for. We wish to be able to evaluate predicative entailments relative to the propositional knowledge, for instance the common sense knowledge that is shared among conversations. We do so by way of the trivial lifts in (44): whenever this is called for, we identify a proposition p with constant function $\lambda x_1 \dots \lambda x_n p$.

(44) **Lifts**
For type reasons, we need to lift propositional types to higher types, for instance in case we wish to evaluate an entailment among predicative expressions relative to a propositional context. So we allow any proposition p to be replaced in the computations with $\lambda x_1 \dots \lambda x_n p$, where $x_1 \dots x_n$ may have any types (= this yields the constant function that outputs p for any arguments).

To illustrate, suppose that we want to trigger a presupposition for *be-pregnant*, of type $<e, <s, t>>$ where s is the type of possible worlds.[31] Let us focus on the entailment that *if x is pregnant, x is female*. First, we could assess this relative to a context c' of type $<e, <s, t>>$ that is true of individual x and world w just in case w is compatible with general shared knowledge, represented at C (so all individuals will have to be considered). So we need to compute the probability that, upon learning that x is pregnant, one antecedently knew that x is female, i.e. the following probability:

(45) $P(\text{believe}_{t-1}\ \text{be-female}(x)\ |\ \text{believe}_{t-1}\ C\ \&\ \text{acquire}_t\ \text{be-pregnant}(x))$

Now it is plausible that this value is in this case very high: upon learning that someone is pregnant, one typically has a prior belief that the person is female. In our preceding example with just two individuals, John and Mary, *acquire_t be-pregnant(x)* is equivalent to: $\text{acquire}_t(\text{be-pregnant}(x)\ \&\ x = \text{Mary})$ (on the assumption that one only believes of women that they are pregnant). Thus (45) boils down to the probability that, upon learning that Mary is pregnant, one antecedently believed that she was female – which is very high.[32]

5.4 Selecting the context and the constituent

Next, we need to select the context with respect to which the triggering rule is assessed. Three natural candidates suggest themselves: the common sense knowledge that can be assumed to be shared across conversations; the specific knowledge that is assumed in a conversation; and the local context of the

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[30] If c', E and p are all of the same type τ that 'ends in t', and can take at most n arguments, then c' $\models$ E => p just in case for all objects $x_1, \dots, x_n$ are objects of the appropriate type, if $c'(x_1) \dots (x_n) = 1$ and $\mathbf{E}(x_1) \dots (x_n) = 1$, then $\mathbf{p}(y_1) \dots (y_n) = 1$ (where $\mathbf{E}$ and $\mathbf{p}$ are the semantic values of E and p respectively).

[31] Schlenker 2009 uses in this case a type $<s, <e, t>>$, but doing so in the present context would force us to write *believe_{t-1} λw(be-female(w)(x))* rather than *believe_{t-1} be-female(x)*. Since the latter is more perspicuous, we adopt the type $<e, <s, t>>$ for predicative expressions.

[32] In greater detail: on the assumption that one only believes of females that they are pregnant, acquire_t be-pregnant(x) is equivalent to (and thus has the same probability as): x = Mary & acquire_t be-pregnant(x). As a result, $P(\text{believe}_{t-1}\ \text{be-female}(x)\ |\ \text{believe}_{t-1}\ C\ \&\ \text{acquire}_t\ \text{be-pregnant}(x)) = P(\text{believe}_{t-1}\ \text{be-female}(x)\ |\ \text{believe}_{t-1}\ C\ \&\ x = \text{Mary}\ \&\ \text{acquire}_t\ \text{be-pregnant}(x))$. If there is little or no uncertainty about Mary's gender, this probability will be very high.

relevant expression, which incorporates information about its linguistic environment (as well as the context of the conversation). To facilitate comparison with lexical theories of presuppositions, we posit that the triggering rule is applied with respect to the most general context that enforces the entailment. This means that when an entailment goes through relative to common sense knowledge, this is the context relative to which triggering is checked. As a result, for all standard triggers, we will only have to do the work once (as in the lexical approach). In case an entailment goes through relative to a local context but not relative to common sense knowledge, local contexts can be used. (In simple cases, the local context will be at least as strong as the context of the conversation; for simplicity, we won't consider cases in which the context of the conversation but not the local context is used.)

(46) **Choice of the context with respect to which the triggering rule is applied**[33]
 a. If E entails p relative to the general knowledge C which is assumed to hold across conversations, then the triggering rule is applied to E and p relative to C, and determines whether p is presupposed or at-issue.
 b. Otherwise, if E entails p relative to the local context c' of E, the triggering rule is applied to E and p relative to c'.

  We could explore a more context-sensitive triggering rule, one in which *all* presuppositions are triggered on the basis of the local context of a clause. But sometimes this would yield too much context-sensitivity.[34] Take *regret*. We assume that *x regrets that p* entails that *x believes that p*, but the challenge is to explain why this is a presupposition. Now it makes good sense to assume that, in general, if one learns that *(x believes that p and) x regrets that p*, one antecedently knew that *x believes that p*. But in special cases this won't be so. Suppose I am in the complaint department of an electronics store. I can ask my colleague working in the same department: *Does your customer regret that she bought an iPhone?* Here the context ensures that upon learning that the customer regrets buying an iPhone, one couldn't have antecedently known that my interlocutor's customer had bought an iPhone. Rather, it is by processing the complaint that one can learn that she bought an iPhone. This predicts that no presupposition should be generated, but this doesn't seem right. (We come back to this issue in Section 10.1, where some arguments *in favor of* greater context-dependency will be discussed).

  Next, we need to specify the size of the constituents with respect to which presuppositions are triggered. It would be catastrophic to generate presuppositions on the basis of the entailments of entire conjuncts, for instance: *Sam smoked and stopped* certainly shouldn't generate a presupposition that Sam smoked. One could avoid the problem by restricting the triggering rule to apply to minimal units (be they words or gestures), but this would be overly restrictive: as we saw in Section 3.2, some expressions such as *press the button* or *walk on the moon* can trigger presuppositions that cannot be ascribed to a lexical trigger. So we must allow the triggering rule to apply to *some* complex expressions. We propose to limit its application by requiring that it should be compatible with the pragmatic meaning of the expression it applies to, and in particular with non-triviality requirements imposed by various pragmatic principles;[35] we leave the principle somewhat under-determined as things stand because it is too early

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[33] At this point, this rule is incomplete. Take *Sam is right that it's raining*. Since *be-right-that* is of a type that 'ends in t', and entails the truth of its complement, the triggering rule can apply relative to common sense knowledge, as desired. The outcome should be that the truth of the complement is at-issue rather than not presupposed (as we argue in Section 6.2, the point is that *x is right that p* comes with an implication that *p* is initially controversial). But we also want to ensure that the triggering rule isn't applied to the entire clause *Sam is right that it's raining*. This could entirely modify the probabilities obtained (I believe a related point was made by M. Esipova in a seminar). The restriction could be effected in two ways: (i) by allowing the rule to apply, but subject to the result of the application of the rule to smaller constituent – in this case subject to the constraint that the embedded clause is at-issue; (ii) by disallowing the same entailment to be considered twice: the entailment that it's raining follows from the lexical entry of *be-right-that* and its arguments (without regard to the local context of the entire clause), and so it should not be considered by the rule at the clausal level after being considered at the predicate level. Precisely defining the latter constraint is not trivial, however; we leave this issue for future research.

[34] Thanks to Harvey Lederman and Una Stojnić for raising related points in a discussion at Princeton in 2018.

[35] An alternative would be to only allow the triggering rule to apply to expressions that contain no logical material, and in particular no connectives and quantifiers. We are not sure how to do this in a principled way, however. For instance, indefinites might have to be allowed in complex expressions that trigger presuppositions, since *x had a bar mitzvah* triggers a presupposition-like inference that *x is Jewish:*

to determine which pragmatic principles constrain the triggering rule.

(47) **Triggering and pragmatic meaning**
     The triggering rule cannot apply if its output contradicts the pragmatic meaning of the expression it applies to.

To illustrate, Stalnaker 1978 posited that an expression must be non-trivial relative to its local context. As a result, the first conjunct of the entire expression *Sam smoked and stopped* should be non-trivial, and for this reason the local context of the entire conjunction shouldn't entail that Sam smoked. This makes it impossible to trigger for the entire conjunction a presupposition that Sam smoked.[36]

6 Applications of the analysis

We turn to some applications of the analysis.

6.1 Initial case studies

We now briefly recapitulate how the proposed theory can formally capture the generalizations stated in Sections 2 and 3.

(i) Cross-linguistic stability (Section 2.1): We noted at the outset that lexical accounts fail to explain why two words that have the same bivalent meaning (e.g. English *stop* and French *arrêter*) also divide its content in the same way among the at-issue and presuppositional components. This follows from the very form of the triggering rule, since it just takes as input a bivalent meaning (and a context) and returns a presupposition. Two words that have the same bivalent meaning must thus be treated in the same way.

(ii) Pro-speech gestures, visual animations and classifier predicates (Sections 2.2–2.4): Since the triggering rule takes as input any bivalent meaning, it is unsurprising that new bivalent meanings produced by an iconic semantics feed this algorithm just as well. Pro-speech gestures, visual animations and classifier predicates convey information that is thus productively divided among the at-issue and presuppositional components by the rule. In fact, we expect that other information-bearing units could feed the algorithm as well, as argued in ongoing work by Guerrini and Migotti (2019), who show that pro-speech onomatopoeias and even musical excerpts can trigger presuppositions.
          In greater detail, let us consider again the example *Will Sally TURN-WHEEL?* in (10)a. It contains a gestural verb that entails the presence of a wheel next to the agent. We can use the context-insensitive version of the triggering rule to assess the probability that, upon learning that someone turned a wheel, one antecedently knew that there was a wheel in that situation.[37] For simplicity, we disregard the time argument of *turn* and evaluate the probability in (48), with C being general world knowledge that holds across conversations:

(48) $P(\text{believe}_{t-1}$ (x is next to a wheel right before t') | believe_{t-1} C & acquire_t x turns a wheel at t')

This is plausibly a high probability because, in cognitive life, one typically perceives a wheel being turned after one already knows about the presence of the wheel. More precisely, on the assumption that

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(i) None of my ten friends has had a bar mitzvah.
=>? each is Jewish

[36] Similarly, even when one assumes that *if Sam believes p, p is true*, the sentence *Sam believes that p* won't presuppose *p* because of Maximize Presupposition (e.g. Heim 1991, Sauerland 2003, 2008). Specifically, *know* triggers a factive presupposition on the basis of the general knowledge that is shared across conversations. This makes it possible to reconstruct standard versions of Maximize Presupposition within the present framework. The pragmatic meaning of *Sam believes that p* will come with a requirement that the local context of the clause should not entail *p*; this, in turn, will block the application of the triggering rule. To see another example (inspired by a remark by M. Abrusán, p.c.), *Sam correctly said that p* won't presuppose *p*: standard Gricean principles of manner (e.g. as formalized in Katzir 2007, Katzir and Fox 2011) imply that *correctly* shouldn't be idle, and thus that *p* shouldn't be presupposed in this case.

[37] Note that the English expression *turn a wheel* displays a completely different behavior, presumably of Maximize Presupposition: if the existence of a (single) wheel is presupposed, the definite description ought to be used.

the discovery process often co-occurs with the event time, situations (tuples) that satisfy acquire$_t$ x turns a wheel at t' will display an overrepresentation of cases with t = t'. The probability in (48) is thus plausibly high, since upon witnessing x turn a wheel, one would typically have prior knowledge of the presence of the wheel. The same analysis explains the contrast between (6)a (= *PICK-UP-GUN-SHOOT*) and (6)b (= *PULL-GUN-SHOOT*): with t = t', upon learning at t that x picks up a gun in evidence on a table and shoots, one would typically have antecedent knowledge of the presence of the gun, whereas this wouldn't be the case if the acquired proposition is that x pulls a gun hidden in his jacket and shoots.

(49) a. P(believe$_{t-1}$ (right before t' x has a gun on the table) | believe$_{t-1}$ C & acquire$_t$ at t' x picks up a gun from the table and shoots)
b. P(believe$_{t-1}$ (right before t' x has a gun in his jacket) | believe$_{t-1}$ C & acquire$_t$ at t' x pulls a gun from his jacket and shoots)

Turning to the helicopter paths with an orthogonal detour or a pause in the middle in the ASL examples in (13)b,d, the key is that these seem to be interpreted as unexpected deviations from a normal trajectory, and thus one would typically learn about the deviation after learning about the final destination. These paths represented a movement from Boston to New York, and thus the entailment that the helicopter goes to New York ends up being presupposed.[38]

(iii) Presupposed contextual entailments (Sections 3.1-3.2): Since our triggering rule takes as input the meaning of an expression relative to a context (which may be more or less general), it is unsurprising that contextual entailments can be turned into presuppositions. Let us briefly consider specific examples.

In (16)(i), repeated as (50)a, the content of the conditional is crucial to obtain the entailment that the person is in fact pregnant. In this case, we cannot trigger the presupposition without appealing to the local context c' of the consequent clause. A standard result of dynamic semantics as well as reconstructions of it (Schlenker 2009) is that the local context c' of the consequent is obtained by intersecting the global context C with the content **p** of the antecedent. Ignoring time arguments, we must compute the probability in (50)b. Here **p** ensure that *the person in front of us* denotes Mary, the responsible thirty-year old; and with that assumption, it is reasonably likely that upon learning that Mary announced to her parents that she is pregnant, one antecedently knew that she is pregnant.

(50) a. If this is Mary, the person in front of us has / has not announced to her parents that she is pregnant.
a'. if p, $^{c'}$q
b. P(believe$_{t-1}$ (Mary is pregnant) | believe$_{t-1}$ C $\cap$ **p** & acquire$_t$(the person in front of us announces that she is pregnant))

The complex trigger *pull the trigger* can be treated in analogous fashion: in local contexts in which *x pulled the trigger* entails that *x shot,* the fact that x's gun is loaded may be turned into a presupposition. A similar reasoning can apply to *walk on the moon*, except that one might not need to have access to a local context to derive the presupposition. The general knowledge C that is shared across conversations probably guarantees that *x walks on the moon* entails that *x is an astronaut.* One can then assess the probability in (51), which is plausibly high: one usually knows that someone is an astronaut before learning that s/he walks on the moon (we disregard again time dependency for simplicity, although a time argument could be added to the verb).

(51) P(believe$_{t-1}$ (x is an astronaut) | believe$_{t-1}$ C & acquire$_t$ x walks on the moon)

(iv) Presupposed implicatures (Section 3.3): There is no particular reason to limit the contribution of an expression to its contextual entailments, and thus taking into account its implicatures when triggering presuppositions is a natural decision, possibly an obligatory one if (47) is understood to

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[38] As mentioned in fn. 10, a curved path (discussed in Schlenker 2019) yields no presupposition that the movement will take place. This can be explained because the movement is not presented as unexpected, and thus in many cases one will learn about the final movement as one learns about the trajectory (a slightly different account is proposed in Schlenker 2019 using a counterfactual analysis of the Triggering Problem; see Appendix III of the present paper for a comparison with the present approach.)

encompass all pragmatic inferences. Kadmon's case of *promise* can be treated along these lines: taking into account the implicated content (to the effect that *y wants z*), the probability in (52) is plausibly high, which means that upon learning that x promises z to y and that y wants, there is good chance one antecedently knew that y wants z.

(52) $P(\text{believe}_{t-1} (y \text{ wants } z) \mid \text{believe}_{t-1} C \& \text{acquire}_t (x \text{ promises } z \text{ to } y \& y \text{ wants } z))$

Similarly, upon learning that there is a post office around the corner and water bills can be paid at post offices, there is a good chance that one antecedently knew that water bills can be paid at post offices: the probability in (53) should thus be high, which would account for Kadmon's examples in (20).

(53) $P(\text{believe}_{t-1} (\text{water bills can be paid at post offices}) \mid \text{believe}_{t-1} C \& \text{acquire}_t (x \text{ promises } z \text{ to } y \& y \text{ wants } z))$water bills can be paid at post offices

While we do not derive *all* of Kadmon's cases, we take it to be a good result that the very idea of a presupposed implicature makes immediate sense in view of our triggering rule, and accounts for some non-trivial examples.[39]

6.2 *Crucial examples for competing theories*

We briefly explain how the present analysis accounts for crucial contrasts that were discussed in connection with competing theories. A full account will depend on a more detailed analysis of the lexical semantics of the relevant constructions, but we try to sketch the main analytical directions.

(i) *Be right* vs. *be aware*: As mentioned in Section 4.1, Abusch's theory needs to stipulate lexical alternatives in order to trigger presuppositions, and in general this is insufficiently predictive; the present analysis does not suffer from this problem. But there are minimal pairs that seem to argue for some lexical arbitrariness, in particular the contrast between *x is right that p* and *x is aware that p*: both convey that *p* is true and x believes it, but they divide this bivalent meaning differently among the presuppositional and at-issue components. On closer inspection, however, we believe that there is a difference between the implications of these two verbs: *x was right that p* usually conveys that *p* was controversial at the relevant time, whereas *x was aware that p* doesn't. Thus **Error! Reference source not found.**b is odd, contrary to **Error! Reference source not found.**a, presumably because one can't quite see why it should be controversial that a professor at UCLA works for University of California.[40]

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[39] Kadmon's example in (ia) (whose presuppositional behavior was discussed in fn. 14) doesn't follow from the present analysis.

(i)   a. Did Sue cry before she finished her thesis?   => Sue finished her thesis
        b. Did Sue finish her thesis after she cried?   ≠> Sue finished her thesis

In general, it is unlikely that upon learning that *p happened before q*, one would antecedently know that *q* but not that *p*, since one tends to know more things about earlier moments. In fact, as we will show in Section 7.1, this this asymmetry is seen 'in action' in presuppositions generated by nonce words. To compound the problem, *Sue finished her thesis after she cried* has roughly the same bivalent content as *Sue cried before she finished her thesis*, but it doesn't trigger the same presupposition, as shown in (i)b. We could posit, however, that some uses of *before* are analyzed in terms of a covert definite description, hence: *before the time at which she finished her thesis*; this would reduce the problem to the triggering of presuppositions by definite descriptions, discussed in Section 9.1.

[40] The examples in (i) lack elegance but are arguably less degraded than (54)b. (ia) might present as currently non-trivial that I held this correct belief (from which it does not follow that the embedded proposition was a matter of controversy). (ib) triggers a presupposition that I held this correct belief, and it is easily accommodated.

(i)   a. (?) I correctly believed that I worked for University of California.
        b. (?) I went by the correct belief that I worked for University of California.

The same point can be made on the basis of the paradigm in (ii): (ii)b suggests, oddly, that it was controversial that Obama should abide by the Constitution (*Obama is right that Trump has to abide by the Constitution* might be more natural if one thinks that the embedded clause is now a matter of controversy).

(54)   When I was a professor at UCLA,
     a. I was aware that I worked for University of California.
     b.??I was right that I worked for University of California.

No matter what the precise source of this controversiality inference, it may affect the triggering rule. Since for both *be right* and *be aware* veridicality follows from the lexical meaning, it is enough to compare probabilities relative to the common sense knowledge C that is shared across conversations, without access to the values of the arguments, as is displayed in (55), where F stands for p (to evaluate the factive presupposition) or x *believes that p* (to evaluate the presupposition that the agent believes the complement).

(55)   a. Be aware: $P(\text{believe}_{t-1} (F) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p \text{ and } x \text{ believes that } p))$
     b. Be right: $P(\text{believe}_{t-1} (F) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p$ **and p is controversial** and x believes that $p)$

The boldfaced conjunct in (53)b will make it less likely that, upon learning that *x is right that p*, one antecedently knows that p is true, with the effect that for $F = p$ we should get a lower probability than in the case of (55)a. The latter is similar to the case of *x knows that p*: chances are that upon learning that both p and the belief that p hold, one had an antecedent knowledge of the state of the world. For $F = x$ *believes that p*, there is no reason to assume a high value in (55)a. Can a high value be justified in (55)b? In case *be right* is interpreted as a speech act, such a high value makes sense: upon learning that x is right in a disagreement about p, one will often have a pre-existing belief about the disagreement and thus about x's beliefs. It's less clear that this extends to silent disagreements. But in any event, the contrast between *be aware* and *be right* as analyzed here seems to go in the right direction, although a full analysis has yet to be developed.

(ii) *Prove* and *be pregnant*: We argued that Abrusán's theory predicts undesirable presuppositions for constructions such as *x proves that p* and *x is pregnant*: we should avoid predicting a presupposition that p is true or that *x was impregnated at least five days ago*. The case of *prove* is similar to that of *be right*: general knowledge guarantees that one usually proves things that were not previously known, which might be enough to guarantee that the probability in (56) isn't too high. As was the case for *be right*, *x proves that p* and *x is right that p* both lexically entail the truth of their complement, hence we only need to assess the relative probability relative to the common sense knowledge that is shared across conversations.

(56) $P(\text{believe}_{t-1} (p) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p \text{ and } x \text{ proves that } p))$

The case of *be pregnant* is straightforward: it is clear that in general upon learning that someone is pregnant, one does not have antecedent knowledge that this person was impregnated at least 5 days before.

(57) $P(\text{believe}_{t-1} (x \text{ was impregnated at least 5 days ago}) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (x \text{ is pregnant}))$

(iii) *Regret* and *deter*:[41] We argued that Abrusán's analysis undergenerates in the case of *x regret that p*, where she fails to generate a presupposition that (at the time of evaluation) *x believes that p*. Here the key seems to us that it is easier to learn about people's beliefs than to learn about their desires, in particular because the former can be inferred from the state of the world and the information that people have access to, unlike the latter. Thus the probability in (58)a is plausibly higher than that in (58)b.[42]

(ii)   a. Obama was aware that he had to abide by the Constitution.
          b. ?Obama was right that he had to abide by the Constitution.
          c. Obama correctly believed that he had to abide by the Constitution.
          d. Obama went by his correct belief that he had to abide by the Constitution.

[41] As noted in Section 4.3.2, (6)b (= *PULL-GUN-SHOOT*) is another case of overgeneration in Abrusán's theory Its analysis was discussed in (49)b.

[42] Three remarks should be added. First, *regret* and other emotional factives arguably have a causal component, of the form: *x's belief that p causes unhappiness in x*. Learning that *x regrets that p* involves learning this causal statement, which might make it more likely that one antecedently knew the cause, i.e. the fact that x believes that p. Second, the present analysis does not seek to derive a factive presupposition for *x regrets that p*; this is because the latter need not be entailed, let alone be presupposed, in discourse of the form *x (wrongly) believes that p and that p*; we briefly revisit this issue in fn. 63. Third, we leave open that speech act interpretations of *x regrets that*

(58) a. P(believe$_{t-1}$ (at t', x believes that p) | believe$_{t-1}$ C & acquire$_t$ (at t', x believes that p and x's belief that p causes unhappiness in x))

b. P(believe$_{t-1}$ (at t', x is unhappy) | believe$_{t-1}$ C & acquire$_t$ (at t', x believes that p and x's belief that p causes unhappiness in x))

We briefly mentioned that *deter* poses a problem for Abrusán's analysis because an entailment pertaining to the event time gets presupposed. The crucial probability is in (59). Now it is plausible that one usually knows about threats before learning about actions take to deter them, which might explain why this probability is high and the entailment gets presupposed.

(59) P(believe$_{t-1}$ (at t', there is a risk that y harms x through q) | believe$_{t-1}$ C & acquire$_t$ (at t', x deters y from q-ing)

7 Properties and predictions

We turn to some general properties and predictions of the present analysis.

7.1 Temporal asymmetries

First, as noted by E. Chemla (p.c.), all other things being equal, we expect that facts about the past should be antecedently known more than facts about the future, and hence there should be a tendency to presuppose information about antecedent states more than about future states. This matters to derive the observation, mentioned in Section 2.1 and discussed by Abrusán 2011, that change-of-state predicates tend to presuppose their initial state.[43] In fact, we can display the temporal asymmetry 'in action' by considering iconic examples as well as nonce words.

Let us consider the gestural example in (60), where the right hand represents a red panel moving towards a white panel depicted by the left hand. In principle, the question could presuppose nothing, or presuppose the initial state, namely that the red panel is initially on the right, or presuppose the final state, to the effect that the red panel reaches the white panel.

(60) *Context:* in a large office, a white panel is positioned behind a red panel.

Will the red panel 🖐$_{\_left\_hand}$ <--- 🖐$_{\_right\_hand}$?

a. Interpreted as: the red panel is to the right of the white panel; will it move towards the white panel?

b. Not interpreted as: the red panel will reach the white panel; will it do so by starting from the right?

Strikingly, the initial state seems to get presupposed, in accordance with what the present theory leads one to expect: on the assumption that one learns that the red panel moved from the right to reach the left panel, it's likely that one initially knew about its initial position but not about its final position.

The same conclusion can be drawn on the basis of new examples involving highly iconic vehicle classifier predicates in ASL, representing in this case two helicopters at different heights, with one of them going up. There are three positions, low, medium, and high. The left-hand helicopter is stable at medium height throughout the examples, while the right-hand helicopter goes up or down by one level in each case. As in (60), one could in principle imagine that the initial state, or the final state, or neither, gets presupposed; but the initial states is invariably presupposed (acceptability appears as a superscript on a 7-point scale, with 7 = best: all examples were maximally accepted; see the Supplementary Materials for quantitative inferential judgments).

(61) Two vehicle classifiers in ASL, and 3 relative positions (addressee's perspective)

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p, meaning *x says that x regrets that p*, display a different behavior from normal interpretations; a related contrast between speech act and non-speech act interpretations is discussed in Section 7.2.

[43] Still, in this area our predictions are distinct from those of Abrusán 2011, for whom all entailments that are not about the matrix event time should be presupposed. First, unlike the present account, Abrusán does not draw a distinction between entailments about past vs. future states. Second, our analysis does not predict that all entailments about prior states should be presupposed: this depends on the details of the discovery process as the relevant contents are acquired in cognitive life, which is why we can explain that *prove* or *establish* do not presuppose the truth of their complement.
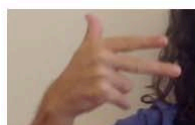
	high		
signer's right hand	↑↓		
	medium	medium	
	↑↓		
	low		signer's left hand

(62) COMPANY HAVE TWO HELICOPTER. TIME 12:05, WON'T CL_left_medium
'The company has two helicopters. At 12:05, with the left-hand helicopter at an intermediate level,
a. [7] CL_right:low->medium.
the right-hand helicopter won't go from a low to an intermediate level.'
=> the right helicopter was initially lower than the other helicopter
b. [7] CL_right:medium->high.
the right-hand helicopter won't go from an intermediate to a high level.'
=> the right helicopter was initially at the same level as the other helicopter
c. [7] CL_right:high->medium.
the right-hand helicopter won't go from a high to an intermediate level.'
=> the right helicopter was initially higher than the other helicopter
d. [7] CL_right:medium->low.
the right-hand helicopter won't go from an intermediate to a low level.'
=> the right helicopter was initially at the same level as the other helicopter
(ASL, 35, 0232)

 One might wish to ascertain that this effect is not a by-product of the iconic examples used here.[44] To do this, we propose to use nonce words, whose meaning needs to be inferred on the basis of limited data. Without offering an experiment, the logic is as follows. We start from a context in which a panel can move to a central position from the left or from the right. An initial learning situation involves the panel moving from the right, and the experimenter saying: *The panel just daxed*. In a second learning situation, the panel moves from the left and the experimenter says: *The panel just wugged*. At this point it is plausible that *dax* means 'move from the right to the center', *wug* means 'move from the left to the center', but none of this prejudges what, if anything is presupposed.

(63) a. *Context:* a mobile panel can reach its central and fixed position from the left, or from the right. It can move in various ways.

 b. *Learning situation 1:* the panel reaches its position from the right: || <--- ■
Shortly thereafter, the experimenter says: *The red panel just daxed*.

 c. *Learning situation 2:* the panel reaches its position from the left: ■ ---> ||
Shortly thereafter, the experimenter says: *The red panel just wugged*.

 d. *Target sentence:* The panel won't dax.

Our strong impression is that if we then say: *Now the panel won't dax*, the inference will be that the panel is initially on the right: the initial state is presupposed.[45] If the bivalent meaning of *dax* is something like *move towards the center from the right*, this is as expected: upon learning that something moved to the center from the right, there is a good chance that one antecedently knew about the original but not about the final position.[46]

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[44] This is a relevant worry because, in ongoing work, we have potential cases in ASL in which a long hold time of the initial position of a classifier predicate tends to induce or strengthen a positional presupposition.

[45] This is all the more striking since one might expect a pragmatic inference to the effect that *the panel will dax or wug* (since these are the two terms that have been introduced). This would lead to the opposite presupposition, namely that the panel will end up in the middle. (Thanks to E. Chemla (p.c.) for discussion.)

[46] In this case, it is important that we assess the triggering rule – and the probability in (i) – relative to the common sense knowledge that is shared across conversations, and thus without all the details of the mechanics of panel movement.

(i) P(believe$_{t-1}$ p | believe$_{t-1}$ C & acquire$_t$ (x moves from the right to the center))

Specifically, if C is this very general knowledge, and *p = x is initially on the right*, it is indeed plausible that one would often learn of x's movement after knowing about x's initial state. But if the details of the conversation and

We conclude that the tendency to presuppose an initial state isn't just exemplified in standard lexical entries (e.g. *stop, start, continue*), but that it is also applied productively to new 'words', as the present theory leads one to expect.

7.2 Gradience

While we have stated the analysis in binary terms (a presupposition is or isn't generated), the role played by the probability threshold makes it likely that *the higher the probability* (that upon discovery the relevant entailment is antecedently known), *the more strongly the presupposition is generated*.[47] Cases of gradience in presuppositional strength have been discussed throughout the literature, from Stalnaker 1974 to Tonhauser et al. 2018. Let us illustrate how a fine-grained analysis might go (we turn to further systematic cases in the following subsections).

Karttunen et al. 2014 show that *x was heroic to Q* yields a stronger factive behavior than *x was fortunate to Q*. We expect that this is because the probability in (64)a is higher than that in (64)b.

(64) a. **heroic:** $P(\text{believe}_{t-1}(x \ Q\text{-ed}) \mid \text{believe}_{t-1} \ C \ \& \ \text{acquire}_t(x \ Q\text{-ed} \ \& \ (x \ Q\text{-ed} => x \ \text{was heroic})))$
      b. **fortunate:** $P(\text{believe}_{t-1}(x \ Q\text{-ed}) \mid \text{believe}_{t-1} \ C \ \& \ \text{acquire}_t(x \ Q\text{-ed} \ \& \ (x \ Q\text{-ed} => x \ \text{was fortunate})))$

This difference might arise if one typically has knowledge about what counts as fortunate, whereas determining what counts as heroic requires greater knowledge of the situation. To greatly simplify, assume that knowledge that Q-ing is fortunate is very stable: upon learning that x Q-ed and that this fact would count as fortunate, one antecedently believed the latter evaluation, as stated in (65)a. This makes it possible to add the boldfaced conjunct in (65)b.

(65) a. $P(\text{believe}_{t-1}(\textbf{x Q-ed => x was fortunate}) \mid \text{believe}_{t-1} \ C \ \& \ \text{acquire}_t(x \ Q\text{-ed} \ \& \ x \ Q\text{-ed} => x \ \text{was fortunate}))$
$= 1$
      b. $P(\text{believe}_{t-1}(x \ Q\text{-ed}) \mid \text{believe}_{t-1} \ C \ \& \ \text{acquire}_t (x \ Q\text{-ed} \ \& \ x \ Q\text{-ed} => x \ \text{was fortunate}))$
$= P(\text{believe}_{t-1}(x \ Q\text{-ed}) \mid \text{believe}_{t-1} \ C \ \& \ \underline{\textbf{believe}_{t-1}(\textbf{x Q-ed => x was fortunate}))} \ \& \ \text{acquire}_t (x \ Q\text{-ed} \ \& \ x \ Q\text{-ed}$
$\underline{=> x \ \text{was fortunate}})$

In this radically simplified case, the probability in (65)b will be zero, i.e. it will be entirely impossible to presuppose the embedded clause. The reason is that the underlined conjunction is of the form *believe$_{t-1}$ p' & acquire$_t$(p and p')*, which can be rewritten more explicitly as: *believe$_{t-1}$ p' & not believe$_{t-1}$(p and p') & believe$_t$ (p and p')*. This simplifies to *believe$_{t-1}$ p' & not believe$_{t-1}$ p & believe$_t$ (p and p')*, and it is clear that conditional on this conjunction, the probability of *believe$_{t-1}$ p* is zero. This is far too extreme for *fortunate*, but this illustrates the potential source of the contrast with *heroic*, if determining what counts as heroic requires more knowledge than determining what counts as fortuante.[48] Importantly,

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situation are known, things change: for *x = the panel* and C = the set-up as described, we know for sure that the panel will end up in the center, but not that it will start from the right.

[47] This can for instance follow if there is uncertainty about the level of the desired threshold. In such a situation, cases with high probability will be more certainly presuppositional than cases with lower probabilities.

[48] Tonhauser et al. 2015 observe that adding *enough* can make evaluative adjectives less projective, a behavior we illustrate in (i):

(i)   a. Was Sam heroic to take action?   => Sam took action
        b. Was Sam heroic enough to take action?   ≠> Sam took action

We believe that the contrast could be explained as follows. *Sam is old enough to watch TV* comes with the implication that there is a contextually determined threshold d such that every person older than d can watch TV. Applying this to (ib), we get for *x is heroic enough to Q* a meaning akin to: (x's heroism ≥ d & for all y, y's heroism ≥ d <=> y Q's) (strictly speaking, it should be *y can Q* rather than *y Q's*, as the latter inference seems to be an implicature, but we disregard this fact for simplicity). The universal component can then be taken to be a stable cognitive fact, with the equality in (ii): the boldfaced addition works as in (65), and the underlined part is due to the fact that, in the conjunction, *x's heroism ≥ d* is equivalent to *x Q's*.

(ii) $P(\text{believe}_{t-1} (x \ Q\text{-ed}) \mid \text{believe}_{t-1} \ C \ \& \ \text{acquire}_t (x\text{'s heroism} \geq d \ \& \ \text{for all } y, y\text{'s heroism} \geq d <=> y \ Q\text{'s}))$
$= P(\text{believe}_{t-1} (x \ Q\text{-ed}) \mid \textbf{believe}_{t-1}(\textbf{for all } \textbf{y, y's heroism} \geq \textbf{d} => \textbf{y Q's}) \ \& \ \text{believe}_{t-1} \ C \ \& \ \text{acquire}_t (\underline{x \ Q\text{'s}}$
$\& \ \text{for all } y, y\text{'s heroism} \geq d <=> y \ Q\text{'s}))$
$= 0$

this analysis is not sufficiently context-sensitive to take into account a further dependency on the propositional argument, discussed in Karttunen et al. 2014 and Tonhauser et al. 2015; we come back to this point in Section 10.1.

7.3 *Know vs. discover: stative and eventive factives*

From Karttunen 1971 and Stalnaker 1974 to Tonhauser et al. 2018 (who employ experimental means), it has been claimed that *know* is a stronger presupposition trigger than *discover*. We believe that, all other things being equal, stative factives are stronger triggers than eventive factives: non-projective readings seem easier in (66)a than in (66)b.

(66) a. If John discovers / realizes / learns / determines / notices / recognizes that he has made a mistake, he will own up to it.
b. If John knows / is aware that he has made a mistake, he will own up to it.

We believe this could be explained on the basis of the simplified bivalent meanings that appear in (67).

(67) a. **Know:** $P(\text{believe}_{t-1} (p) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p \ \& \ x \text{ believes } p))$
b. **Discover:** $P(\text{believe}_{t-1} (p) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p \ \& \ x \text{ believes } p$ **& x didn't previously believe p**$))$

In this simplified analysis, the only semantic difference lies in the boldfaced conjunct in (67), which might be responsible for lowering the probability relative to (67)a: among all the cases in which one learns that *x correctly believes p but didn't believe p before*, some will be cases in which one *also* didn't previously know that p.[49] This weakening of the antecedent probability should extend to other eventive factives, such as *learn*.

7.4 *Regret vs. grumble: thought act and speech act emotives*

While *x regrets that p* entails that *x believes that p* and *x grumbles that p* entails that *x says/believes that p*, the first entailment is presupposed but the second isn't (we disregard here the further factive entailment that *regret* often has). This seems to be a more general fact: as shown in (68), speech act verbs with an emotive component tend not to presuppose the 'saying' component, whereas emotive thought act verbs tend to presuppose the 'believing' component; the generalization extends to the (rather different) French verbs in (69):

(68) a. Will John regret/be (annoyed)/be irritated/be angry that his assistant is overworked?
=> John will believe that his assistant is overworked
b. Will John (complain)/grumble/bitch that his assistant is overworked?
≠> John will say/believe that his deputy is overworked

(69) a. Jean va-t-il être irrité/embêté que son adjoint soit sous-payé?
Jean will-he be irritated/annoyed that his deputy be-subj. underpaid?
'Will Jean be irritated/annoyed that his deputy is underpaid?'
=> Jean will believe that his deputy is underpaid (=>? Jean's deputy will be underpaid)
b. Jean va-t-il vitupérer/fulminer que son adjoint est sous-payé?

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[49] A full analysis must take into account time dependency of the relevant propositions by endowing verbs (and thus propositions) with time arguments. With this refinement, we must compute the probabilities in (i), where not just x and but also t' and t" are random variables (note that the time of acquisition of the belief that *x knows/discovers that p* need not correspond to the time of the knowing/discovering, nor of p). As before, the crucial difference between (ia) and (ib) is the boldfaced conjunct in (ib).

(i)   a. **Know:** $P(\text{believe}_{t-1} (p_{t"}) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p_{t"} \ \& \ x \text{ believes}_{t'} p_{t"}))$
b. **Discover:** $P(\text{believe}_{t-1} (p_{t"}) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p_{t"} \ \& \ x \text{ believes}_{t'} p_{t"}$ **& not x believes$_{t'-1}$ p$_{t"}$**$))$

Now it is clear that that for t = t', the argument in the text will go through: among the situations in which one learns that x correctly believes that p but didn't believe p before, some will be situations in which one didn't believe *p* before either. As long as in other cases (for t ≠ t') the probability in (ib) is not higher than the probability in (ia), the argument in the text will go through: overall, the probability in (ib) should (due to the case t = t') be a bit lower than the probability in (ia).

Jean will-T-he be irritated/annoyed that his deputy be-subj. underpaid?
'Will Jean rant/fulminate that his deputy is underpaid?'
≠> Jean will say/believe that his deputy is underpaid (≠> Jean's deputy will be underpaid)

Plausibly, one learns about a person's beliefs before learning of their attitudes about these beliefs, especially when we infer the beliefs on the basis of external facts. Concretely: if I see that John's deputy is overworked, I may often infer that John believes this to be the case. To infer that this fact causes John to be annoyed, I need much more information about John. For this reason, upon learning that John believes with annoyance that his deputy is overworked, one will plausibly antecedently know that John believes his deputy is overworked. This contrasts with verbs of speech that convey annoyance, such as *complain*: upon learning that John said with annoyance that his deputy is overworked, I might not antecedently know that he said such a thing, as it is probably in one and the same event that the claim and the annoyance were expressed.

In sum, we believe the contrasts in (68)-(69) hold because the probability in (70)a is greater than that in (70)b.

(70) a. P(believe$_{t-1}$ (x believes that p) | believe$_{t-1}$ C & acquire$_t$(x believes p & x is annoyed because x believes p))
b. P(believe$_{t-1}$ (x says that p) | believe$_{t-1}$ C & acquire$_t$ (x says p & x is annoyed while x says p))

8   *Only* and *even*

In this section, we argue that our triggering rule can explain why certain components of the truth-conditional contribution of *only* and *even* are presupposed while others are not. As in all other cases, we must take for granted a bivalent meaning, feed it to our triggering rule, and show that it yields a correct division between presupposition and assertion. While there is some agreement about the various readings obtained with *only* and *even*, different authors have different views on the division between lexical specifications and pragmatic enrichments in this area. We can to some extent be neutral on this matter, since pragmatically enriched meanings can serve as an input to the triggering algorithm (as we saw in Sections 3.3 and 6.1). In this section, we mostly follow the very detailed empirical discussion of Greenberg 2019, without necessarily adopting her theoretical conclusions, and we ask whether the various readings she describes can be fed to our triggering rule to derive the correct presuppositions.

Importantly, we will follow Greenberg (and much of the literature) in assuming that *only* and *even* make reference to certain contextual orderings, notably in terms of entailment/expectedness or desirability. We will crucially assume that our triggering rule has access to the precise nature of the ordering, which will derive different presuppositions for different readings.

8.1   *Only*

As a first approximation, we can take the bivalent meaning of *only* to have the components in (71):[50]

(71) *Only p is true* is true given a set of scalar alternatives Alt(p) and an ordering < iff:
(i) p is true;
(ii) p is low on <;
(iii) for every q in Alt(p), if q > p, q is false.
(We will often write (iii) as: *p$^+$ is false*.)

In the simplest case, 'p is low on <' means that one expects that something logically stronger than *p* is true. A simple example is given in (72).

(72) a. Only Sam came, with alternatives Alt(a) = {Sam came, Ann came, Sam and Ann came}
b. Bivalent meaning of (a):
(i) Sam came;
(ii) it is expected that Sam and Ann came;
(iii) it's not the case that Sam and Ann came.

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[50] We write 'as a first approximation' because it is known that for scalar implicatures and *only* alike, the alternatives that get negated must be selected by way of a more discriminating algorithm. See Spector 2016 for a systematic comparison of different way to do so.

Since *only* enforces the entailments in (71), we can assess whether each is presupposed in view of the nature of the ordering (which we take to be given). We will start by assuming that whether the proposition p is low on $<$, i.e. in this case whether something stronger is expected, is a very stable cognitive fact ,in the following sense (already used in Section 7.2): if *p is low on* $<$ is believed at t, it was believed at t-1, hence the assumption in (73).

(73) $P(\text{believe}_{t-1}(p \text{ is low on } <) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p \text{ is true and } p \text{ is low on } < \text{ and } p^+ \text{ is false})) = 1$

This has two consequences. First, the fact that p is low on $<$ should be presupposed. Second, thanks to (73) we can rewrite the crucial probability in (74)a with the addition of the boldfaced conjunct in (74)b. This can be further rewritten as in (74)c because in the present case 'p is low on $<$' means that something stronger than p is expected to hold.

(74) a. $P(\text{believe}_{t-1}(p \text{ is true}) \mid \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p \text{ is true and } p \text{ is low on } < \text{ and } p^+ \text{ is false}))$
b. $= P(\text{believe}_{t-1}(p \text{ is true}) \mid \text{believe}_{t-1} C \ \& \ \textbf{believe}_{t-1}(\textbf{p is low on} <) \ \& \ \text{acquire}_t(p \text{ is true and } p \text{ is low on } <$
and p^+ is false))
c. $= P(\text{believe}_{t-1}(p \text{ is true}) \mid \textbf{believe}_{t-1}(\textbf{a stronger alternative than p is expected}) \ \& \ \text{believe}_{t-1} C \ \& \ \text{acquire}_t$
$(p \text{ is true and } p^+ \text{ is false}))$

The question becomes: given that (i) one antecedently expected something stronger than p to be true, and (ii) one learned that p but nothing stronger was true, what is the probability that one antecedently believed p? In view of (i), and the fact that nothing ended up refuting p, this probability is plausibly high, which should make p presupposed. This result is appropriate in view of some standard projection tests, as illustrated in (75).

(75) a. Did only Sam come?
b. I doubt that only Sam came.
a, b => Sam came

A second case discussed in the literature is that in which 'p is low on $<$' means that p has low desirability (Klinedinst 2004, 2005; Beaver and Clark 2008), as illustrated in (76)a.

(76) a. Bill only got his BA from CAL STATE, with alternatives Alt(a) = {Bill got his BA from Cal State, Bill got his BA from UCLA, Bill got his BA from Harvard}
(Klinedinst 2004)
b. Bivalent meaning of (a)
(i) Bill got his BA from Cal State
(ii) Bill's getting his BA from Cal State is low on the scale of desirability relative to Alt(a)
(iii) it's not the case that Bill got his BA from UCLA or Harvard

Klinedinst 2004 argues that the prejacent (i.e. the argument of *only*) need not be presupposed, as shown by the projection tests in (77).

(77) a. It is unlikely that Bill only got his BA from CAL STATE (his parents were very rich, he was a great student, etc.)
≠> Bill got his BA from Cal State
b. There is no way/possibility that Bill only got his BA from CAL STATE (his parents were very rich, he was a great student, etc.)
≠> Bill got his BA from Cal State

From the present perspective, this is unsurprising: if the scale $<$ is one of desirability rather than expectation, (74) can be rewritten as in (78) and does not lead to the conclusion that p was probably antecedently believed: the fact that a proposition is low on a scale on desirability doesn't have any clear impact on its chance of being believed.

(78) $P(\text{believe}_{t-1}(p \text{ is true}) \mid \textbf{believe}_{t-1}(\textbf{p is low on a scale of desirability}) \ \& \ \text{believe}_{t-1} C \ \& \ \text{acquire}_t (p \text{ is true}$
and p^+ is false))

Beaver and Clark 2011 propose an analysis in which *Bill only got his BA from CAL STATE* presupposes that Bill got his BA from a place at least as good as Cal State.[51] We leave this issue for

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[51] In their words (p. 251), the presupposition of *Only p* is that "the strongest true alternatives in the CQ [= Current Question] are at least as strong as the prejacent" [= *p*].

future research, but note that this result is expected *when* we have an inference of the type: *if p is low on the desirability scale, then one can expect something at least as good as p to be true*. This would take us back to the reasoning we made relative to scales of expectedness in (74)-(74), where we posited that *if p is low on a scale of expectedness, then one can expect something at least as strong as p*. When this inference doesn't go through, we believe that the 'at least as good' inference needn't be presupposed. In (79)(a), it does not seem to be presupposed that the random programmer looking for a job at Google had a degree from a place at least as good as Harvard. Strikingly, the facts seem to change if an entailment/expectedness-based scale is used instead, as in (79)(b). A similar contrast seems to hold between (79)(a') and (79)(b').

(79) Two MIT engineers at Google briefly chatted with a programmer who later interviewed for a job.
A: Why didn't the guy we talked to get the job?
(a) B: Maybe he only had a degree from HARVARD (and not from MIT).
≠> he has a degree from an institution that is at least as good as Harvard
(b) B: Maybe he only had ONE degree from Harvard.
=> he has a degree from Harvard
(a') B: If this guy only has a degree from HARVARD, he won't get the job.
≠> he has a degree from an institution that is at least as good as Harvard
(b') B: If this guy only has ONE degree from Harvard, he won't get the job.
=> he has a degree from Harvard

A third case, discussed in Greenberg 2019, is that in which the inference that the prejacent is low on the relevant scale just doesn't arise. Why this case arises need not concern us here, as we are solely interested in its consequences for the presupposition triggering rule (Greenberg 2019 offers a theory). Greenberg's examples are given in (80)-(81):

(80) (Context: My mother and I are organizing a weekend for the whole family. We discuss the location where the families of my two sisters, Rina and Esti, will stay)
Mom: Rina has four kids so she will stay in the this apartment. Esti has only three kids, so she can stay in that apartment. (Orenstein & Greenberg 2013, cited in Greenberg 2019)

(81) (The average height for men here is 1.78m).
John is tall. He is 16 years old and already 1.85m tall. His 14 years old brother Bill is a bit shorter – he is only 1.83m tall. (Greenberg 2019)

In our terms, what fails to arise in this case is the meaning component in (71)(ii), to the effect that the prejacent p is low on the ordering $<$. In particular, there is no inference that something higher was expected. Correspondingly, we should not have a presupposition that the prejacent is true (nor the weaker presupposition that the prejacent or something higher should be true). The prediction seems plausible in view of the data in (82).

(82) a. In our hotel, we really get all sorts of customers. Our last customers had 7 kids. If the next ones only have 5, we'll know how to keep them busy.
≠> our next customers will have at least 5 kids
b. [Uttered in Berlin] A tour guide's life can be unexpectedly complicated. My last customer was 2m10, and fitting him in my vintage Trabi proved to be a challenge. If my next customer is only 1m90 tall, I'll know what to do.
≠> my next customer will be at least 1m90 tall

One final word is in order. Much recent work on implicatures posits a covert exhaustivity operator *Exh*, which behaves like *only* in its purely logical component, but lacks any implications about the fact that the prejacent is low on the relevant scale (e.g. Chierchia et al. 2012, Spector 2016). Since this component is crucial to generate the presupposition that p is true, we expect that *Exh p* should not trigger this presupposition – a desirable result since this operator is standard defined in non-presuppositional terms (e.g. Bar Lev and Fox 2017).

8.2   Even

Turning to *even*, Greenberg 2019 argues for the treatment sketched in (83). In simple cases, 'p is high on $<$' means that p is unexpected.

(83) *Even p* is true is true given a set of scalar alternatives Alt(p) and an ordering < iff:
    (i) p is true;
    (ii) p is high on <.

As summarized in Greenberg 2019, much of the literature posits a third component, to the effect that an alternative to *p* (different from *p*) is true. This inference is present and in fact presupposed in (84). But if the relevant alternative is given (without being asserted) in the preceding discourse, the presupposition doesn't seem to materialize, as seen in (84)b (which contrasts in this respect with standard presuppositional cases such as those in (84)c).[52]

(84) a. Maybe my advisee will even make multiple$_F$/five$_F$ mistakes.
    => my advisee will (likely) make mistakes
    b. Ann says that this applicant is incompetent. Maybe he is even multiply$_F$ incompetent, but in any event the boss will hire him.
    ≠> this applicant is incompetent.
    c. Ann says that this applicant is incompetent. Maybe the boss knows/is annoyed that he is, but in any event he'll hire him.
    => this applicant is incompetent.

Greenberg also argues that in some cases there are clear contrasts between *also*, which carries an additive component, and *even*, which does not, as illustrated in (85).[53]

(85) A: How was the exam? Did you pass?
    B. Yes. I even / #also [got 90]$_F$. (Greenberg 2019)

We thus follow Greenberg in doing without the additive component in the bivalent meaning of *even* – which also has the advantage of simplicity.[54]

Strikingly, whereas the prejacent is presupposed in some uses of *only*, it is at-issue with *even*, as can for instance be seen in (84). This can be explained by the present analysis. We assume (just as we did in similar cases for *only*) that *p is high on <* is a stable cognitive fact, with the simplified assumption in (86), which has the effect that *p is high on <* gets presupposed.

(86) P(believe$_{t-1}$(p is high on <) | believe$_{t-1}$ C & acquire$_t$ (p is true and p is low on < and p$^+$ is false)) = 1

Then, by analogy with (74), we make use of the equality in (87) in order to determine the presuppositional status of *p* in *even p*:

(87) P(believe$_{t-1}$(p is true) | believe$_{t-1}$ C & acquire$_t$(p is true and p is high on <))
    = P(believe$_{t-1}$(p is true) | **believe$_{t-1}$(p is high on <)** & believe$_{t-1}$ C & acquire$_t$(p is true and p is high on <))

As in the case of *only*, < could be a scale of unexpectedness, or desirability. But in either case, the fact that *p* was antecedently believed to be desirable/unexpected should not give rise to the inference that *p* was antecedently believed. This explains why the prejacent is not presupposed.[55]

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[52] It has been argued in the literature focus that given material that does not have an antecedent in the discourse tends to get presupposed (see for instance Büring 2012). It is thus essential to consider discourses that justify this givenness component to determine whether there is a presupposition that ought to be derived by a triggering rule, or a more general (and defeasible) effect of focus.

[53] Greenberg 2019 also cites examples such as (i), in which the prejacent is incompatible with its alternatives:

(i)   A: Is Claire an [assistant]$_F$ professor?)
        B: No, she's even an [associate]$_F$ professor. (Rullmann 1997; cited in Greenberg 2019)

[54] See also Szabolcsi 2018 for a derivation of the contrast between *too* and *even* on the basis of a mechanism of double-exhaustification.

[55] Charnavel 2016 argues that just like there is a covert version of *only* (namely *Exh*, discussed in Section 8.1), there is a covert version of *even*, which she writes as *E,* and whose appearance is triggered (among others) by French *propre* ('own'), as in (i). The lexical entry she posits for *E* is similar to (83), but without component (iii). She further argues that component (ii) (in our terms, 'p is high on <') is presupposed, as shown for instance by the fact that it projects out of the antecedent of the conditional in (i). That this should be a presupposition is expected from the present theory.

Since *p* trivially entails *p or some lesser alternative is true,* we might wonder whether this entailment is presupposed (by analogy with the question we asked, following Beaver and Clark 2008, about the inference that *p or some better alternative is true* for *only p*). This does not seem to be invariably the case. In (88), there appears to be a contrast between *even*, which does not trigger a presupposition that an alternative is true, and *too*, which arguably does trigger such a contrast. (The linguistic context greatly matters: as we explain below, there are environments in which *too* triggers weaker-than-expected presuppositions.)

(88) a. I somewhat doubt that Ann Smith is an academic. But you know what? Assume that she is even a Distinguished Professor. I won't invite her to this particular workshop.
b. #I somewhat doubt that Ann Smith's partner is a professor. But you know what? Assume that Ann Smith too is a professor. I won't invite them to this particular workshop.

From the present perspective, the question is whether the probability in (89) ought to be high.

(89) P(believe$_{t-1}$(p or some lower alternative on < within Alt(p) is true) | believe$_{t-1}$(p is high on <) & acquire$_t$(p is true and p is high on <))

This would seem to be scale-dependent: in the case of (88)a, it is not clear that upon learning that Ann Smith is a Distinguished Professor one would antecedently know that she is an academic, but contextual details might greatly matter. We leave this as an open question, but note that the contrast between *even* and *too* in (88) can be derived by the present theory: as we will argue below, the presupposition of *too* is generated in a different, and less context-sensitive, fashion.

While several questions will require a closer investigation, we conclude that the present analysis offers a first stab at an understanding of the presuppositional differences between *only* and *even*, as well as of the fine-grained presuppositional differences among different readings of *only*.

9 Definite descriptions and anaphoric triggers

We now extend our analysis to definite descriptions and anaphoric triggers. We argue that some expressions (notably expressions of type e) may give rise to referential failure, which we encode by the value #. This is a limited form of lexical presupposition failure. If we allowed functional meanings to output # (in particular when they take # as input), we would be back to a theory with lexical stipulations for all presupposition triggers: once a function can output #, we can just as well say that *x stop smoking* outputs # unless *x smoked*. We do not take this path. Instead, we take # to be strictly limited to cases of referential failure, especially for expressions of type e (other atomic types, such as the type i of times, could be added as well; we will propose an extension to further anaphoric cases in Section 9.2). In particular, we do *not* posit that predicative meanings may yield # when they take # as an input; rather, they output falsity in this case, and the challenge is to explain why a sentence such as *the director smokes* can trigger a presupposition despite having only 'true' and 'false' as possible semantic values.

Cases of referential failure may be thought to exist in cognitive life, for instance when one realizes that a 'mental file' one had created for someone seen in the distance fails to refer because there was in fact nothing there. What matters for present purposes is that such cases will be very rare, with the result that *upon learning that object x satisfies property P* (e.g. *smokes*), *one would typically have a pre-existing belief that x ≠ #*. We will then argue that this case can be extended to provide an analysis of various triggers that have an anaphoric component: the fact that the anaphoric element refers will tend to be presupposed.[56]

9.1 *Expressions of type e*

We adopt the standard Strawson/Frege treatment of definite descriptions: these can fail to denote, and

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(i) Si Jean a trahi son propre PATRON, il va être viré.
If Jean has betrayed his own BOSS, he is-going-to be fired
'If John betrayed his own BOSS, he is going to be fired.'

[56] An alternative would be to do without referential failure altogether, and show that Russellian truth conditions can be fed to our initial triggering rule to output Frege/Strawson presuppositions. A further alternative would build on familiarity/unfamiliarity requirements (as in Heim 1983b), possibly by analogy with (6)a (familiar gun, presupposed) and (6)b (unfamiliar gun, not presupposed). We leave these possibilities for future research.

hence they may have as their value the object # (corresponding to referential failure). We further adopt a standard analysis of pronouns (e.g. from Heim and Kratzer 1998, following Cooper 1983) whereby these too fail to denote if the denotation specified by the assignment function fails to satisfy their pronominal features.

For notational simplicity, we write as c the pair of a world of evaluation and an assignment function (e.g. c = <w, s>), and we write c(i) for the value assigned to a variable i (e.g. c(i) = s(i)). We thus posit the rules in (90), and seek to derive the presuppositional behavior illustrated in (91).

(90) a. [[the President]]^c = # unless there is exactly one president in c_w; otherwise, the unique president in c_w.
      b. [[she$_i$]]^c = # unless c(i) ≠ # and c(i) is female in c_w). Otherwise, c(i).

(91) a. Does the President smoke?
      => there is exactly one president
      b. Does she$_i$ smoke?
      => the denotation of i exists and is female

We take the object # to lie in the extension of no elementary predicate. Thus [[smoke]]^c(x) = 1 entails that x ≠ #. The question is whether we can explain why this entailment is treated as a presupposition. In the terms of the present theory, we need to compute the probability in (92).

(92) P(believe$_{t-1}$ x ≠ # | (believe$_{t-1}$ C) & (acquire$_t$ (x ≠ # and x smokes))

As mentioned, cases of referential failure may be thought to exist in cognitive life, for instance when realizes that a 'mental file' one had created for someone seen in the distance fails to refer because there was in fact nothing there. On the assumption that these cases are very rare, the probability in (92) will be high, so that it will be presupposed that the argument of *smokes* isn't #.[57]

9.2   *Extension to other anaphoric triggers*

We will now propose to extend the analysis to further presupposition triggers that have an anaphoric component. We argue that this is the case of *too*. Its special behavior can be illustrated by contrasting *co-sponsoring* with *sponsoring too*, as in (93): the former construction can to some extent lend itself to a non-presuppositional reading, whereas the latter cannot.

(93) In an admissions meeting:
      a. If Ann Smith co-sponsors Pierre Martin, we should admit him.
      ≠>? someone besides Ann Smith sponsors Pierre Martin
      b. If Ann Smith too sponsors Pierre Martin, we should admit him.
      => someone besides Ann Smith sponsors Pierre Martin

Part of the behavior of *too* is due to its focus semantics, as assumed in the literature following for instance Rooth 1992. So *Ann Smith too sponsors Pierre Martin* requires an antecedent of the form *Y sponsors Pierre Martin*, where *Y* is a focus alternative to *Ann Smith*. We will not seek to explain this fact, which should derive from focus theory. On the other hand, we wish to understand why it is presupposed (rather than asserted) that this antecedent is true. We will argue that this is because, as in Rooth's theory, *too$_i$* comes with a propositional index *i*, with a requirement that *i* should be true. And this component can be analyzed in terms of an extension of the (standard) theory that we adopted for *she$_i$*. The latter denotes # unless the value of the index *i* is female. Similarly, in *too$_i$*, we posit that *i* is (as a first approximation) represented as *i^{realized}* and fails to denote unless its propositional denotation is

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[57] Two remarks should be added.
(i) The present approach would lead one to expect that the existence inference is not presupposed in verbs of existence, such as *Does the Loch Ness monster exist*? We believe this prediction is correct, but also think this fact could be analyzed in different ways, so we do not discuss it further here.
(ii) We do not discuss clefts in this piece, but note that some authors analyze them as covert definite descriptions. Thus Percus 1997 takes *It is John that Mary saw* to be the spell-out of a Logical Form akin to: *the person Mary saw is John*. See Büring and Križ 2013 for a more recent discussion of clefts which is explicitly compatible with Percus's insights (because idiosyncrasies the authors find in clefts can be replicated with identity statements involving definite descriptions).

true (we will soon slightly revise the 'truth' component).[58]

To make things simple and concrete, we will treat too_i by analogy wit the expression *in addition to this$_i$*, where i is a proposition-denoting variable, which could give rise to presupposition failure. We will also consider *in addition$_i$*, which we take to have roughly the same behavior, but with an anaphoric component that is covert. The first thing to note is that too_i and *in addition$_i$* come with a strong presupposition about their antecedent – as a first approximation (to be refined soon), it must be true.

(94) a. It's cold outside. If it's raining too, I won't go out.
　　　b. #It's not cold outside. If it's raining too, I won't go out.
　　　c. #It's unlikely to be cold outside. If it's raining too, I won't go out.

(95) a. It's cold outside. If in addition (to this) it's raining, I won't go out.
　　　b. #It's not cold outside. If in addition (to this) it's raining, I won't go out.
　　　c. #It's unlikely to be cold outside. If in addition (to this) it's raining, I won't go out.

The similarity between too_i and *in addition$_i$* is further highlighted by two subtle facts. One was noted by van der Sandt and Geurts 2001 (following Zeevat 1992, 2000): something weaker than truth of the antecedent is presupposed by *too*. Thus (96)a,b and (97)a,b contrast with (96)c and (97)c respectively. (94)c and (95)c respectively. The requirement seems to be that the antecedent is possibly/likely true, not that it is in fact true.[59]

(96) a. It might be cold outside. If it's raining too, I won't go out.
　　　b. It's likely to be cold outside. If it's raining too, I won't go out.
　　　c. #It's unlikely to be cold outside. If it's raining too, I won't go out.

(97) a. It might be cold outside. If in addition (to this) it's raining, I won't go out.
　　　b. It's likely to be cold outside. If in addition (to this) it's raining, I won't go out.
　　　c. #It's unlikely to be cold outside. If in addition (to this), it's raining, I won't go out.

This possibility requirement seems hard to locally accommodate. This is a bit difficulty to see in (94)b,c and (95)b,c, as locally accommodating (within the *if*-clause of the second sentence) the assumption that it might be cold outside would quasi-contradict the first sentence. But in (98)a,b, the first clause is embedded under *believe*, and thus the problem doesn't arise. Still, local accommodation of the possibility presupposition of the antecedent in the scope of the *if*-clause seems extremely difficult.

(98) a. #Robin says that it's #unlikely/^{ok}likely to be cold outside. If it's raining too, I won't go out.
　　　b. #Robin says that it's #unlikely/^{ok}likely to be cold outside. If in addition (to this) it's raining, I won't go out.

By contrast, when this possibility presupposition is satisfied, as in (96)a,b-(97)a,b, one can locally accommodate in the scope of the *if*-clause that the antecedent is true. In other words, in these cases, the *if*-clause is understood to mean *if it's cold and it's raining outside, I won't go out*.

Our main conclusion is that *too* behaves very much like *in addition (to this)*: the propositional antecedent is presupposed to be possible, and this requirement is hard to locally accommodate. Once the possibility of the antecedent is presupposed, on the other hand, local accommodation of the truth of that antecedent seems to some extent permissible. We propose to analyze these cases in terms of an anaphoric argument treated by analogy with *it* in (90)b. The particle *too* will come with further requirements due to its focus-sensitive semantics, so for simplicity we only consider *in addition$_i$*. The analysis is sketched in (99): *in addition* takes a covert propositional variable, and an overt propositional argument. Its bivalent meaning is that both arguments are true and they are not in an entailment relation.

(99) a. In addition, it is raining.
　　　analyzed as:
　　　a'. [[in addition i^{possible}] it is raining]

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[58] This entails that there are cases of referential failure beyond atomic types, but we leave a proper characterization of 'referential failure' for future research.

[59] The example that appears in Sandt and Geurts 2001 is reproduced in (i):

(i)　　　A. Harry may well have dinner in New York.
　　　　　B. John is having dinner in New York, too.

b. [[in-addition]]^c(q)(p) = 1 iff p = 1 and q = 1 and p doesn't entail q and q doesn't entail p.
c. If i is a proposition-denoting variable, [[i^{possible}]]^c = # unless c(i) is possible in c_w. If ≠ #,   [[i^{possible}]]^c = c(i).

With this background, we can analyze this case on a par with other cases of reference to #: the predicate *in-addition* will pragmatically derive a presupposition that its arguments have a value different from #.

More work will be needed to determine whether this line of inquiry can be extended to further strong triggers, i.e. triggers whose presuppositions are hard to locally accommodate.[60]

10   Extensions and alternatives

10.1   Greater context-dependency?

Our current theory predicts that the triggering rule should be assessed relative to different contexts for different entailments: if *E* entails *p* relative to the common sense knowledge C that is shared across conversations, one should assess relative to C whether *p* is turned into a presupposition; if *E* only entails *p* relative to its local context c', then c' should be used instead. This predicts great context dependency for the triggering of contextual entailments, and no context dependency for more standard presupposition triggers. The first point seems to be correct but the second prediction is too conservative.

We argued above that *inform* doesn't lexically entail the truth of its complement, but often does so on the basis of contextual information. The latter doesn't just matter to enforce the entailment, but also to determine whether that entailment counts as an epistemic precondition, as illustrated in (100).

(100) a. Smith is 200km away from the South Pole. Will he inform his mother tomorrow that he has reached it?
≠> tomorrow Smith will have reached the South Pole.
b. Smith is 20km away from the South Pole. Will he inform his mother tomorrow that he has reached it?
=> tomorrow Smith will have reached the South Pole

Both sentences leave open whether Smith will have reached the South Pole tomorrow, although this is more likely in (100)b than in (100)a. There seems to be a stronger tendency to generate a presupposition in (100)b than in (100)a. This can be explained if we evaluate probabilities of the full propositions relative to the local context of the target sentence. Replacing *correctly believes* with *correctly announces* in (102), we ask: upon learning that Smith correctly announces to his mother that that he has reached the South Pole, what is the probability that one antecedently knew he had reached it? It should be greater in the '20km away' than in the '200km away' scenario, hence the result.

But the same contextual effects can be found with *know*: depending on whether an entailment counts as an epistemic precondition *in a local context*, it may or may not be treated as a presupposition. Consider the sentence in (101)c in the contexts described in (101)a,b.

(101) Smith is on a difficult expedition to reach the South Pole on skis.
a. Context 1: early 20th century - we have no way of tracking Smith
b. Context 2: 21st century scenario - we have access to Smith's GPS coordinates
c. Target sentence: If Smith knows he has reached the South Pole, he'll send his family a message.

Our impression is that in Context 2, *know* displays its usual behavior and triggers a presupposition that

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[60] In particular, we leave for future research an extension of the analysis to *again*, which shares several properties with *too* (and was explicitly treated in a parallel fashion in van der Sandt and Huitink 2003). As seen in (i), *applying again* is far harder to locally accommodate than *re-apply*. As seen in (ii), the presupposition of *again* seems to merely pertain to the possibility of a certain proposition pertaining to the past. And once this possibility presupposition is satisfied, local accommodation of the truth of the past proposition is arguably possible, as (ii)b can mean: *if she goes home for Thanksgiving and again for Christmas, her parents will be delighted*.

(i) On an admissions committee:
a. If Smith is re-applying, we shouldn't admit him.   ≠> Smith student applied before
b. If this Smith is applying again, we shouldn't admit him.   => Smith applied before

(ii)   a. Floppy may be on the run at Christmas, but she will never be on the run again. (van der Sandt and Huitink 2003)
        b. It's possible/likely/#unlikely that Ann will go home for Thanksgiving. If she goes home again for Christmas, her parents will be delighted.

Smith has reached the South Pole. But this inference isn't as strongly present in Context 1. We believe this is because *relative to the context of the conversation* (rather than world knowledge that is shared across conversations), the value of the probability in (102) is lower in Context 1 than in Context 2, because in Context 1 Smith is our only source of information about his position, hence upon learning that Smith correctly thinks he reached the South Pole, one would typically not antecedently know he has in fact reached it – unlike in Context 2, where tracking devices make it possible to know independently of Smith where he is.[61]

(102) P(believe$_{t-1}$(Smith has reached the South Pole) | believe$_{t-1}$ c' & acquire$_t$(Smith correctly believes he has reached the South Pole))

Not just the local context but also the nature of the arguments seems to matter. Consider (103) uttered in the various contexts in (104). In Context 1 and Context 2, chances are that upon learning that Ann correctly believes that she made an error in the proof, one would not antecedently know that there is in fact one. The probability that one has this antecedent knowledge is higher in Context 1' and Context 2', where one is more likely to have information that Ann herself doesn't have.

(103) Did Ann realize she made an error in her proof?

(104) a. Context 1:　　　Uttered by Ann's genius advisor
=> Ann made an error in the proof
a'. Context 1':　　　Uttered Ann's 13-year old brother.
Why is my sister so distraught? …
≠> Ann made an error in the proof
b. Context 2:　　　Ann is a good professional mathematician.
≠> Ann made an error in the proof
b'. Context 2':　　　Ann is a beginning student.
=> Ann made an error in the proof

The nature of the complement seems to matter as well, as illustrated in (105).

(105) From a non-mathematician, to a mathematician:
a. Did you realize you made an error in your proof?
≠> the addressee made an error in the proof
b. Did you realize you mistreated your students?
=> the addressee mistreated students

Because one typically has greater access to a mathematician's behavior than to the correctness of their proofs, the difference makes sense: upon learning that the mathematician realized that they mistreated their students, one would typically antecedently believe that they did so; but upon learning that they realized that they made an error in their proof, one might not antecedently know there was an error.[62]

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[61] Similar contextual effects can be found with complex triggers. We noted in fn. 35 *x had a bar mitzvah* triggers the (weak) presupposition that *x is Jewish*. But this isn't invariably the case. For instance, the context in (i) is compatible with an inference that all ten students are Jewish, but the presupposition doesn't seem to materialize.

(i) A teacher reads the local newspaper that lists the most noteworthy social events of the past year:
None of my ten students had a bar mitzvah.
≠> all of them are Jewish

The reason is plausibly that in this context, upon learning that a student x had a bar mitzvah, one might not antecedently believe that x is Jewish, because the source of the information, namely the newspaper, provides both components (being Jewish and having a bar mitzvah) at once. The same analysis might capture the observation, made by Geurts 1994 and Simons 2001, that *stop* fails to trigger a presupposition in (ii): in the context of the conversation, upon learning that the nervous stranger smoked but no longer does, one would typically not antecedently believe that the stranger smoked before.

(ii) [To a stranger:] Why are you so nervous? Have you recently stopped smoking? (Geurts 1994, Simons 2001)
[62] A related point pertains to Tonhauser and Degen's (2019) finding that "higher-probability content is more projective than lower-probability content". For instance, *Does Sandra know that Julian dances salsa?* projects a factive presupposition more strongly if the context specifies that Julian is from Cuba than if it specifies that he is from Germany. This fact may be interpreted in a deflationary fashion: in the second case, it is less likely that the

Karttunen et al. 2014 provide further examples of argument-dependency: *x wasn't fortunate to Q* displays a completely different behavior depending on whether *Q-ing* is independently thought to be fortunate (as in (106)a) or unfortunate (as in (106)b).

(106) a. Paul wasn't fortunate to take the best piece.
      ↛> Paul took the best piece
    b. Paul wasn't fortunate to take the worst piece.
      => Paul took the worst piece (after Karttunen et al. 2014, experimental results in their Figure 7)

The analysis we sketched in (65) can be applied, but with a crucial twist: the nature of the arguments *x* and *Q* must be taken into account by the triggering rule. Once this is done, we can reproduce the reasoning developed in (65) on a sentence-by-sentence basis. If it is generally known that Q-ing is fortunate, then upon learning that x Q-ed and that this fact counts as fortunate, one would typically *not* antecedently believed that x Q-ed, hence the result that this entailment is not presupposed.

The upshot is that a triggering rule must be explored which is more sensitive to local contexts and arguments than our 'official' one. But the risk is to get too much flexibility in this way. As we noted at the outset, if I ask my colleague working in the complaints department *Does your customer regret that she bought a iPhone?*, we still seem to get a presupposition that the customer bought an iPhone, although in this very special case one would learn of the buying by learning about the complaint.[63]

10.2 A restatement in terms of probabilistic satisfaction?

Our algorithm is based on the idea that entailments that are *likely* to be antecedently known in cognitive life *must* be locally presupposed in sentences. What explains that we turn a likelihood into an obligation of a presupposition?

One answer has to do with exploitation, the communicative phenomenon whereby small probabilities can have big communicative effects by way of strategic reasoning.[64] To be concrete, consider the sentence *Robin stopped smoking*, which we will abbreviate as *pp'*, with *p = used to smoke*, and *p' = doesn't currently smoke*. Let us start from a slightly different theory in which *if p has probability (1-ε) of being antecedently known in cognitive life, then it should also have probability (1-ε) of being entailed by its local context*. This is different from our 'official' theory, in which we require a certainty that *p* should be entailed by its local context. But communicative rationality might explain why the probability (1-ε) gets turned into 1. The intuitive reason is this: in most cases, the speaker has a choice between uttering *pp'* and uttering *(p and pp')*, which might be a bit more costly (because it's longer) but

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presupposition is satisfied, which should facilitate local accommodation. Alternatively, one may want to derive this result from the triggering rule. Since *know* lexically entails the truth of its complement, our 'official' triggering rule is insufficiently context-sensitive to capture this fact. But the more context-sensitive rule discussed in the present section might provide better predictions. The key is that, all other things being equal, the rule is sensitive to the probability that certain entailments are antecedently believed. Specifically, applying Bayes's rule, the propositional triggering rule in (38) can be reformulated as in (i). The boxed term is the probability that one antecedently believed the purported presupposition.

(i) $P(\text{believe}_{t-1} \mathbf{p} \mid \text{believe}_{t-1} \text{c}' \& \text{acquire}_t \mathbf{E}) = [P(\text{believe}_{t-1} \text{c}' \& \text{acquire}_t \mathbf{E} \mid \text{believe}_{t-1} \mathbf{p}) / \text{believe}_{t-1} \text{c}' \& \text{acquire}_t \mathbf{E}]$ * $\boxed{P(\text{believe}_{t-1} \mathbf{p})}$

[63] A further extension we leave for future research pertains to (38)(i), the requirement that something should be entailed relative to a local context before it can be turned into a presupposition. One could explore a simpler presupposition triggering rule whereby *p* is presupposed by *E* just in case $P(\text{believe}_{t-1} \mathbf{p} \mid \text{believe}_{t-1} \text{c}' \& \text{acquire}_t \mathbf{E})$ is sufficiently high. This would allow for non-entailed presuppositions. Such cases seem to exist: while (i)a triggers a presupposition that John made a mistake, (i)b doesn't even trigger the inference (let a alone a presupposition) that he did. This is may be thought to be a version of the 'Proviso Problem', but it could potentially be re-analyzed within the present framework (see Geurts 1999 for an account within DRT, however).

(i)   a. Does John regret/Is John annoyed that he made a mistake.
           => John made a mistake
           b. John wrongly believes he made a mistake, and he regrets/is annoyed that he did.

[64] Thanks to Leon Bergen (p.c.) for emphasizing the importance of exploitation in the present context.

will definitely not allow *p* to be treated as presupposed (for independent reasons pertaining to the non-triviality of *p*, as in Stalnaker 1978). On the revised theory, uttering *pp'* will only yield a probability (1-ε) that *p* should be treated as presupposed. But the hearer can reason that *if* the speaker had wanted *p* not to be presupposed, she could have uttered *(p and pp')* instead. Assuming that the cost of the additional length is low enough, her uttering *pp'* alone is proof that she *definitely* wants *p* to be presupposed. A more precise reasoning is outlined in Appendix II.[65]

10.3 A restatement in terms of counterfactual reasoning?

Schlenker 2018 sketched a different triggering algorithm, based on the idea that entailments get presupposed if they are 'stable' in terms of counterfactual reasoning. Specifically, if we write as *pp'* the conjunction of the at-issue and of the presuppositional components we can apply the test in (107). It asks that one assume, relative to the assumptions of the context, that *pp'* holds true. Then it assesses the counterfactual stability of the entailment *p* by asking whether, on the counterfactual assumption that *pp'* had not been the case, *p* would still have held. The test is crucially applied with a non-monotonic analysis of counterfactuals.

(107) Stability of entailments (counterfactual test)
Assume that *pp'* holds (relative to the Context Set C), and that C |= pp' => p (i.e. *p* is a contextual entailment of *pp'*). If (counterfactually) *pp'* had not been the case, would *p* still have been the case?
If → represents the counterfactual conditional, this can be represented as:
C, pp' |= (not pp') → p[66]
Yes: treat *p* as a presupposition.
No: do not treat *p* as a presupposition.

Consider for instance the pre-existence of an object, as in *x TURN-WHEEL at t₁* (discussed in Section (10)). The intuition is that, on the assumption that x turned a wheel, if this had not been the case, the wheel would still have been in front of x. Here it is of course crucial that the counterfactual should not mean that if *pp'* had not been the case, it would *necessarily* have been the case that *p*, as this requirement would be far too strong. But the non-monotonic semantics for counterfactuals explored by Stalnaker (1967), Lewis (1973a) and others is far weaker: it only asks that we consider the *closest* worlds in which *pp'* fails to be the case, and determine whether in those worlds *p* still holds. The desirable answer – that the wheel would still have been in front of the agent – is intuitively plausible in this case.
We show in Appendix III that in very special cases, this analysis makes the same predictions as a version of our official proposal. Specifically, if our probabilistic parameter is set to 1, and if belief revision for counterfactual *if F, G* is effected by going back to the most recent belief state that didn't entail *F*, we get a very close match between the two theories. In other words, there is a common core to the triggering rule based on counterfactual reasoning and the triggering rule developed in this piece, although in the general case they are rather different.

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[65] An alternative would be to follow Lassiter 2012 and take local context theory to come with a probabilistic component itself. In a nutshell, Lassiter argues that the correct notion of satisfaction in local context theory isn't that a context c' entails a presupposition *p*, but that the probability of *p* relative to c' is sufficiently high. His arguments pertain to the so-called Proviso Problem, which need not concern us here. While there is a general affinity between the present proposal and Lassiter's, a probabilistic extension of the present theory would deliver the rule in (i)a, which mentions the probability that one's antecedent belief state entail a presupposition. By contrast, Lassiter's rule has to do with the probability of a presupposition relative to a local context, as stated in (i)b. We leave an exploration of possible unifications for future research.

(i) If in cognitive life P(believe$_{t-1}$ p | (believe$_{t-1}$ c') & (acquire$_t$ pp')) ≥ a, then in a linguistic environment…
a. the probability that the local context of *pp'* entail *p* is ≥ a, i.e. P(c' |= p) ≥ a.
b. the probability of *p* relative to its local context is ≥ a, i.e. P(p | c') ≥ a.

[66] This should be read as follows: in each world w that is in C and satisfies the (classical, non-presuppositional) meaning of *pp'*, w makes true the counterfactual conditional (not pp') → p.

10.4   A communicative reinterpretation?

We based our discussions on discovery processes in cognitive life, but we could reinterpret the analysis purely communicative terms. In a nutshell, we could replace the triggering rule in (108)a with that (108)b, where the notion *one believes that F* is replaced with *one assumes that F*, pertaining to the assumptions of a conversation, and *one acquires the belief that F* is replaced with *one asserts that F*.

(108) a. $P(\text{believe}_{t-1}(p) \mid \text{believe}_{t-1} C \,\&\, \text{acquire}_t pp') \geq a$
b. $P(\text{assume}_{t-1}(p) \mid \text{assume}_{t-1} C \,\&\, \text{assert}_t pp') \geq a$

   This analytical direction faces two challenges. First, there is a serious risk of circularity if we reduce triggering to the expected behavior of expressions which themselves trigger presuppositions: it could be that the triggering rule in (108)b is correct for the uninteresting reason that *pp'* is typically conveyed with an expression that presupposes *p* (one could imagine that this bivalent content can be expressed as *(p and pp')*, which doesn't trigger a presupposition, but this could be rare for a variety of reasons). Second, for the crucial cases in which we need a triggering rule for expressions that could not have a lexical presupposition (such as those discussed in Sections 2.2, 2.3, 2.4 and 3), this analysis can hardly rely on actual communicative experience to compute the relevant probabilities (since these are nonce words), and it needs to assess what *would* be taken for granted in counterfactual communicative interactions. This wouldn't require a theory of how facts are discovered (as in our 'official' theory), but rather of how conversations develop. We do not know whether this line of analysis can be made plausible.

11   Conclusion

We have reached two conclusions. First, a lexical approach to presupposition generation isn't just insufficiently explanatory. It also fails to account for presuppositions triggered by a variety of non-lexical triggers: iconic expressions (pro-speech gestures and classifier predicates), contextual triggers, complex triggers, and possibly even some nonce words (as in (63)). Second, a simple triggering rule can be derived from accepted presupposition projection mechanisms. Within different versions of dynamic semantics, a presupposition must be trivial relative to a local context. We proposed that this rule derives from an attempt to guarantee that entailments that are typically inert in cognitive life are also semantically inert relative to their local context. This led us to posit a rule whereby if upon learning that *pp'*, one typically antecedently knew that *p*, p should be treated as presupposed.

   There are multiple open issues on the empirical and on the theoretical side. On the empirical side, the experimental investigations of iconic triggers by Tieu et al. 2019 could be extended to other non-lexical triggers, be they iconic or not; the nonce words we briefly discussed in (63) would also lend themselves to experimental investigations. The issue of the context-dependency of the triggering rule, as well as its interaction with the syntactic environment, would also need to be investigated in greater empirical detail. Most crucially, one would need to assess on independent grounds the conditional probabilities that we relied on at every juncture.

   On the theoretical side, several key issues were left open: (i) how much should the triggering rule 'see' of the linguistic context of an expression? and how large is the syntactic domain over which presuppositions can be triggered? (ii) what is the full range of triggers that can be accounted for? While we sketched extensions to definite descriptions, *even*, *only*, and *too*, the work ahead remains considerable.

Appendix I
Definitions and sample derivations

Notation: When there is no confusion, we use *p* both for the syntactic object and for its semantics value. In cases where the contrast matters (such as in the initial definitions), we boldface semantic values, so that **p** refers to the semantic value of *p*.

Main Principles: Our main principles are as follows:

(109) **Triggering rule**

For a certain probability threshold a, for an expression *E* whose type 'ends in t', trigger a presupposition *p* with respect to context c' if:

(i) c' |= E => p, and
(ii) $P(believe_{t-1} \mathbf{p}(x_1) ... (x_n) | believe_{t-1} c'(x_1) ... (x_n) \& acquire_t \mathbf{E}(x_1) ... (x_n)) \geq a$

where P (• | _) is the subjective conditional probability of • given _, **E** and **p** are the semantic values of *E* and *p* respectively, t is a random time variable, $x_1 ... x_n$ are random variables ranging over objects of the appropriate types to yield a truth value when given as arguments to **E** and c', *acquire_t • : not believe_{t-1} • and believe_t •*.

(110) **Lifts**

For type reasons, we need to lift propositional types to higher types, for instance in case we wish to evaluate an entailment among predicative expressions relative to a propositional context. So we allow any proposition **p** to be replaced in the computations with $\lambda x_1 ... \lambda x_n \mathbf{p}$, where $x_1 ... x_n$ may have any types (= this yields the constant function that outputs **p** for any arguments).

(111) **Choice of the context with respect to which the triggering rule is applied**

a. If *E* entails *p* relative to the general knowledge C which is assumed to hold across conversations, then the triggering rule is applied to *E* and *p* relative to C, and determines whether *p* is presupposed or at-issue.
b. Otherwise, if *E* entails *p* relative to the local context c' of *E*, the triggering rule is applied to *E* and *p* relative to c'.

(112) **Triggering and pragmatic meaning**

The triggering rule cannot apply if its output contradicts the pragmatic meaning of the expression it applies to.

Probability of open sentences:[67] We take as primitive the probability of open sentences, but it can be derived, as discussed in Lassiter 2011 and Leblanc 1962. The latter starts by assigning weights to individuals or tuples of individuals; these can be interpreted as the chance of sampling these individuals. For simplicity, Leblanc assumes that each individual is named by exactly one individual constant, and he passes on the weights of the (tuples of) individuals to the (tuples of) constants. For instance, consider the open sentence with two free variables *w outlives x* (Leblanc 1962 p. 70). Leblanc takes *weight($<W_{i1}$, W_{i2})* to be the chance of encountering the i-th pair (of individuals named by the constants) $<W_{i1}, W_{i2}>$ within the cross product of the set of individuals. If there are n individuals (and thus n^2 pairs of individuals), the probability of the open sentence *w outlives x* is given by the formula in (113) (where W_{i1} *outlives* W_{i2} is a closed formula with constants replacing *w* and *x*).

(113) $P(w \text{ outlives } x) = \sum_{1 \leq i \leq n^2} weight(<W_{i1}, W_{i2}>) \bullet P(W_{i1} \text{ outlives } W_{i2})$

Extending Leblanc's example, the conditional probability *P(w is in good health | w outlives x)* can be computed as in (114) when $P(w \text{ outlives } x) \neq 0$ (Leblanc 1962 p. 71, D13.3):

(114) P(w is in good health | w outlives x) = P(w is in good health and w outlives x) / P(w outlives x)[68]

$= \sum_{1 \leq i \leq n^2} weight(<W_{i1}, W_{i2}>) \bullet P(W_{i1} \text{ is in good health and } W_{i1} \text{ outlives } W_{i2}) / \sum_{1 \leq i \leq n^2} weight(<W_{i1}, W_{i2}>) \bullet P(W_{i1} \text{ outlives } W_{i2})$

The triggering rule in (109)(ii) has the general form $P(A(t-1, x_1, ... , x_n) | B(t-1, t, x_1, ... , x_n))$, where *A* and *B* make reference to beliefs in certain propositions at certain times, and Leblanc's

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[67] Thanks to Dan Lassiter (p.c.) for discussion of this point.
[68] Note that the definition is standard, but the conjunction *w is in good health and w outlives x* ensures the formula in the numerator inherits all the free variables found in the denominator.

derivation strategy can in principle be applied to it.

Time dependency: For simplicity, we will often disregard the time dependency of object language formulas. But when we do take it into account, as in $PICK\text{-}UP\text{-}GUN\text{-}SHOOT(x_1)(t_1)$, we will take cases in which one discovers at t that $PICK\text{-}UP\text{-}GUN\text{-}SHOOT(x_1)(t_1)$ to include an overrepresentation of cases in which the discovery process co-occurs with the event time, i.e. $t = t_1$. This may follow from the intuition that in cognitive life many such discoveries are made through direct perception, in which case the probability of such discoveries when $t \neq t_1$ will be low. Alternatively, using Leblanc's derivation of the probabilities of open sentences, we may take tuples of the form $<t-1, t, \dots t_1 \dots >$ to have a disproportionately greater weight when $t = t_1$.

Examples

(115) **Gestural verb: *TURN-WHEEL*, without time dependency** (= (10)a)

a. Will Sally TURN-WHEEL?

=> Sally is next to a wheel

b. Triggering applies to *TURN-WHEEL*: by iconic semantics (not discussed here), the iconic predicate entails the proximity of a wheel, hence relative to the common sense knowledge C which is shared across conversations,

$\lambda x\, C \models$ TURN-WHEEL $\Rightarrow$ close-to-wheel

where *TURN-WHEEL* and *close-to-wheel* are both of predicative type and where $\lambda x\, C$ is a trivial lift of C (= a constant function outputting C).

c. Triggering applies if $P(\text{believe}_{t-1}\ \text{close-to-wheel}(x_1)\ |\ \text{believe}_{t-1}\ [\lambda x\ C](x_1)\ \&\ \text{acquire}_t\ \text{TURN-WHEEL}(x_1)) \geq a$. Since $[\lambda x\ C](x_1) = C$, this simplifies to

$P(\text{believe}_{t-1}\ \text{close-to-wheel}(x_1)\ |\ \text{believe}_{t-1}\ C\ \&\ \text{acquire}_t\ \text{TURN-WHEEL}(x_1)) \geq a$

This probability is plausibly high, as upon learning that someone turned a wheel, one typically antecedently knew that they were close to a wheel.

(116) **Gestural verb: *PICK-UP-GUN-SHOOT*, with time dependency** (= (6)a)

a. The situation will be tense, but the person sitting next to me will not PICK-UP-GUN-SHOOT.

=> the person sitting next to me will have a gun in front of him

b. Triggering applies to *PICK-UP-GUN-SHOOT*: by iconic semantics (not discussed here), the iconic predicate entails the presence of a gun on the table, hence relative to the common sense knowledge C which is shared across conversations,

$\lambda x\ \lambda t'\ C \models$ PICK-UP-GUN-SHOOT $\Rightarrow$ close-to-gun

where *PICK-UP-GUN-SHOOT* and *close-to-gun* are both of predicative type (taking time dependency into account) and where $\lambda x\ \lambda t'\ C$ is a trivial lift of C (= a constant function outputting C).

c. Triggering applies if $P(\text{believe}_{t-1}\ \text{close-to-wheel}(x_1)(t')\ |\ \text{believe}_{t-1}\ [\lambda x\ \lambda t'\ C](x_1)(t_1)\ \&\ \text{acquire}_t\ \text{PICK-UP-GUN-SHOOT}(x_1)(t_1)) \geq a$. Since $[\lambda x\ \lambda t'\ C](x_1) = C$, this simplifies to

$P(\text{believe}_{t-1}\ \text{close-to-wheel}(x_1)(t')\ |\ \text{believe}_{t-1}\ C\ \&\ \text{acquire}_t\ \text{PICK-UP-GUN-SHOOT}(x_1)(t_1)) \geq a$.

On the assumption that most situations in which one learns PICK-UP-GUN-SHOOT$(x_1)(t_1)$ co-occur with t_1, and are due to direct perception, this probability is plausibly high: with $t = t_1$, many cases in which one sees someone picking up a gun from the table are ones in which one antecedently knew that the gun was on the table.

(117) **Gestural verb: *PULL-GUN-SHOOT*, with time dependency** (= (6)b)

a. The situation will be tense, but the person sitting next to me will not PULL-GUN-SHOOT.

$\neq>?$ the person sitting next to me will have a gun in his jacket

b.-c. The analysis is similar to that in (116), with *PULL-GUN-SHOOT* replacing *PICK-UP-GUN-SHOOT*. The key difference is that the crucial probability (= $P(\text{believe}_{t-1}\ \text{close-to-wheel}(x_1)(t')\ |\ \text{believe}_{t-1}\ C\ \&\ \text{acquire}_t\ PICK\text{-}UP\text{-}GUN\text{-}SHOOT(x_1)(t_1)))$ is plausibly low: in cases of acquisition of knowledge by direct perception, upon learning that someone pulls out a gun hidden in their jacket, one would not antecedently know that they had a gun.

(118) **Iconic classifier predicates, without time dependency** (= (13)d)

a. WITHIN 1-HOUR OUR COMPANY BIG HELICOPTER BOSTON$_a$ NEW-YORK$_b$ IF a-*GO-helicopter-large__ __-b*, 2-EMAIL-1.

'If within the next hour our company's big helicopter makes a pause on its way from Boston to New York, e-mail me.'

=> the big helicopter will go from Boston to New York

b. Triggering applies to the predicate *GO-helicopter-large__ __*, the 2-rotored helicopter classifier tracing a path from the Boston locus to the New York locus with a pause in the middle. We assume that it takes an individual argument and two location arguments.

There are two entailments to consider: *2-rotored*, whereby the helicopter has two rotors (as depicted by the classifier), *go-from-to*, whereby the helicopter will go from the denotation of locus *a* to the denotation of locus *b*. We write *2-rotored(x_3)* for x_3 *is 2-rotored*, *go-from-to(x_1)(x_2)(x_3)* for x_3 *goes from x_1 to x_2* and *GO-helicopter-large__ __(x_1)(x_2)(x_3)* for x_3 *is a 2-rotored helicopter that goes from x_1 to x_2 with a pause in the middle*.

c. Triggering outputs *2-rotored* as a presupposition in case:

$P(\text{believe}_{t-1}\ 2\text{-rotored}(x_3)\ |\ \text{believe}_{t-1}\ \lambda x\ C\ \&\ \text{acquire}_t\ \text{GO-helicopter-large\_\_ \_\_}(x_1)(x_2)(x_3)) \geq a$.

This probability is plausibly high, as upon learning that something is a 2-rotored helicopter that goes from one place to another with a pause in the middle, one typically antecedently knew that this thing is a 2-rotored helicopter.

Triggering outputs *go-from-to* in case:

$P(\text{believe}_{t-1}\ \text{go-from-to}(x_1)(x_2)(x_3)\ |\ \text{believe}_{t-1}\ \lambda x\ C\ \&\ \text{acquire}_t\ \text{GO-helicopter-large\_\_ \_\_}(x_1)(x_2)(x_3)) \geq a$.

This probability is plausibly high because the pause is likely unplanned whereas the rest of the path is planned: upon learning that large helicopter x_1 went from x_2 to x_3 with an unexpected pause in the middle, one typically antecedently knew that x_1 was to go from x_2 to x_3.

(119) **Contextual triggers with local contexts: *announce*, without time dependency** (= (16))

We write as a subscript the local context c' of the target expression, *announced*.

a. If this is Mary, the person in front of us has not $^{c'}$announced to her parents that she is pregnant.

=> Mary is pregnant

b. Triggering rule applies to *announce* relative to its local context c'.

Following the general rules of Schlenker 2009, c' is defined as the strongest predicative element x such that, relative to the context c of the conversation, no matter what y and p are,

c $\models^{c' \rightarrow x}$ If this is Mary, the person in front of us has not [c' and announced] to y that p

   $\leftrightarrow$ If this is Mary, the person in front of us has not announced to y that p

We write *announce(p)(x_2)(x_1)(w)* for: x_1 *announce p to x_2 in w*. Without fully computing the local context c', it is clear that it guarantees that:

for all world w and object d, if c'(p)(x_2)(x_1)(w) = 1, then **w is in c and x_1 = Mary**, as the fact that w is in c and the agent is Mary is redundant with information provided by the context c and the syntactic environment.

c. We assume that *in the local context c', x announces that p* entails that *p* is true. Since c' and announce have the same (high) type, this can be written as:

c' $\models$ announce => $\lambda p \lambda x_2 \lambda x_1\ p$

The propositional argument gets presupposed in case:

$P(\text{believe}_{t-1}\ [\lambda p \lambda x_2 \lambda x_1\ p](p)(x_2)(x_1)\ |\ \text{believe}_{t-1}\ c'(p)(x_2)(x_1)\ \&\ \text{acquire}_t\ \text{announce}(p)(x_2)(x_1)) \geq a$. Since $[\lambda p \lambda x_2 \lambda x_1\ p](p)(x_2)(x_1) = p$, this simplifies to $P(\text{believe}_{t-1}\ p\ |\ \text{believe}_{t-1}\ c'(p)(x_2)(x_1)\ \&\ \text{acquire}_t\ \text{announce}(p)(x_2)(x_1)) \geq a$

This is, roughly, the probability that one would typically antecedently know a proposition upon learning that Mary truthfully announced it at a costumed party. It is unclear whether this probability should be high. (As discussed in Section 7.2 in connection with *be irritated that* vs. *grumble that*, we might in general expect speech act factives to give rise to relatively weak presuppositions because when learning that *x (truly) announced/grumbled that p*, one might discover the fact that p through that very speech act).

(120) **No presupposition for demonstrate-class verbs, without time dependency** (= (32))

Unlike Anand and Hacquard 2014, we take *x proves that p* to lexically entail that *p* is true, and thus we evaluate the triggering rule with respect to the common sense knowledge that is shared across conversations. But *x proves that p* comes with a meaning component to the effect that *p is highly non-trivial*, which will be enough to block presupposition generation.

a. Do the bloody gloves prove that Mary committed the murder?

≠> Mary committed the murder

b. Relative to the common sense knowledge C which is shared across conversations,[69]

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[69] Note that we are lifting the types of C and **p** in accordance with (110). (ia) gives rise to the conditions in (ib).

$\lambda p \lambda x \ C \models \lambda p \lambda x \ prove(p)(x) \implies \lambda p \lambda x \ p$

and thus we apply the triggering rule relative to C.

c. Triggering leads to the presupposition of the propositional argument if

$P(believe_{t-1} [\lambda p \lambda x \ p](p_1)(x_1) \mid believe_{t-1} [\lambda p \lambda x \ C](p_1)(x_1) \ \& \ acquire_t [\lambda p \lambda x \ prove(p)(x)](p_1)(x_1)) \geq a$. This simplifies to $P(believe_{t-1} p_1 \mid believe_{t-1} C \ \& \ acquire_t \ prove(p_1)(x_1)) \geq a$. But *prove($p_1$)($x_1$)* has an entailment to the effect that *p_1 is non-trivial*, which makes it unlikely that one would antecedently believe *p_1*.

(121) ***Be right that p* vs. *be aware that p*, without time dependency** (discussed in (55))

a. Is Robin aware / right that it is raining?

$\implies$ it is raining / $\not\implies$ it is raining

b.-c. The analysis is similar to (120), and in the end we need to assess the following probabilities:

$P(believe_{t-1} p_1 \mid believe_{t-1} C \ \& \ acquire_t \ be\text{-}right(p_1)(x_1)) \geq a$

$P(believe_{t-1} p_1 \mid believe_{t-1} C \ \& \ acquire_t \ be\text{-}aware(p_1)(x_1)) \geq a$

As argued in Section 6.2, *be-right(p_1)(x_1)* has a lexical component whereby *p_1* is non-trivial, which makes it less likely that one would antecedently know its truth; *be-aware(p_1)(x_1)* lacks this lexical component.

(122) **Pull the trigger, without time dependency** (= (2)b)

a. Will [this hunter $^{c'}[\lambda i \ t_i$ pull the trigger]]?, where c' represents the local context of the VP.

$\implies$ this hunter's gun is loaded

b. Let us call *h* the denotation of *this hunter*. Relative to a global context c for the conversation, the local context c' of the VP has the value: $c' = \lambda x \lambda w \ x = h$ and $w \in c$.[70]

Triggering applies to $\lambda i \ t_i$ *pull the trigger*, abbreviated as *pull-the-trigger*, relative to c', we have:

$c' \models \lambda x \ pull\text{-}the\text{-}trigger(x) \implies \lambda x \ x$'s rifle is loaded.[71]

c. Triggering applies if $P(believe_{t-1} \ loaded\text{-}gun(x_1) \mid believe_{t-1} \ c'(x_1) \ \& \ acquire_t \ pull\text{-}the\text{-}trigger(x_1)) \geq a$. Since $c' = \lambda x \lambda w \ x = h$ and $w \in c$, this simplifies to:

$P(believe_{t-1} \ loaded\text{-}gun(x_1) \mid believe_{t-1} \ (c \ and \ x_1 = h) \ \& \ acquire_t \ pull\text{-}the\text{-}trigger(x_1))$

This probability is plausibly high, as upon learning that a hunter has pulled the trigger of a loaded rifle, one typically antecedently knew that the rifle was loaded.

Only and *even*
Assumptions

(123) **Bivalent meaning of *only*, for different orderings < and sets of alternatives** (the bracketed part won't always be present, following Greenberg 2019)

Only p is true given a set of scalar alternatives Alt(p) and an ordering < iff:

(i) p is true;

[(ii) p is low on <;]

(iii) for every q in Alt(p), if q > p, q is false.

(124) **Bivalent meaning of *even***

Even p is true given a set of scalar alternatives Alt(p) and an ordering < iff:

(i) p is true;

(ii) p is high on <.

(125) **Additional assumptions**

a. We assume that the triggering rule applies to *only* and *even* while taking into account the nature of the

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(i)   a. $\lambda p \lambda x \ C \models \lambda p \lambda x \ demonstrate(p)(x) \implies \lambda p \lambda x \ p$

b. for every proposition p, individual x and world w, if C(w) = 1 and demonstrate(p)(x) = 1, then p(w) = 1

[70] As in Schlenker 2009, **c'** is defined as the strongest predicative element x such that, relative to the context c of the conversation, no matter what the predicate *P* is,

$c \models^{c' \to x}$ [[this hunter] [c' and P]] $\leftrightarrow$ [[this hunter] P]

On the assumption (adopted in Schlenker 2009) that *P* is non-modal, it is clear that for $x = \lambda x \lambda w \ x = h$ and $w \in c$ the condition is satisfied. Now suppose that for $w \in c$, **c''**(w)(h) = 0. Taking P to be the tautological predicate, we would have that $w \models^{c'' \to x}$ [[this hunter] P], but $w \not\models$ [[this hunter] [c'' and P]]. This shows that **c'** $= \lambda x \lambda w \ x = h$ and $w \in c$ is the strongest value that satisfies the condition, and hence this is the local context of the VP.

[71] We do not seek to derive the presupposition that there is a rifle, which derives from the behavior of *the*. But the presence of the rifle doesn't suffice to explain the inference that it is loaded.

scale.

b. We assume that the fact that a proposition is low or high on the scale is cognitively stable. In particular, in view of the common sense knowledge C which is shared across conversations:[72]

(i) (for *only*) P(believe$_{t-1}$(p is low on <) | believe$_{t-1}$ C & acquire$_t$ (p is true and p is low on < and for every q in Alt(p), if q > p, q is false)) = 1

b. (for *even*) P(believe$_{t-1}$(p is high on <) | believe$_{t-1}$ C & acquire$_t$ (p is true and p is high on < and for some q in Alt(p), q < p and q is true)) = 1

Examples

(126) ***Only* with entailment-based scales and a 'low' component** (= (79)b)

q > p means: q is asymmetrically entails p

p is low on < means: an alternative in Alt(p) stronger than p is expected

a. Only p

e.g. Maybe Sam only has ONE degree from Harvard, with alternatives Alt(a) = {Sam has one degree from Harvard, Sam has two degrees from Harvard} (with an 'at least' reading of numerals)

=> Sam has a degree from Harvard

b. Relative to the common sense knowledge C which is shared across conversations, *only p* entails (123)(i)-(iii), and we evaluate the presuppositional status of each in turn.

c. Starting with (ii), by (125)b(i),

P(believe$_{t-1}$(p is low on <) | believe$_{t-1}$ C & acquire$_t$ (only p)) = 1 so *p is low on <* is presupposed.

Turning to (i), by (125)b(i) again,

P(believe$_{t-1}$(p is true) | believe$_{t-1}$ C & acquire$_t$ (only p)) = P(believe$_{t-1}$(p is true) | believe$_{t-1}$ C & **believe$_{t-1}$(an alternative in Alt(p) stronger than p is true)** & acquire$_t$(only p))

In view of the boldfaced condition, we need to consider situations in which one antecedently believes that something stronger than *p* is true, and one learns that *p* but nothing stronger is true. Many such situations are plausibly ones in which one antecedently believes that *p* is true, hence this value is plausibly high, and *p* is presupposed.

Turning to (iii), we need to consider each alternative *q* that entails *p*. Since one antecedently expected something stronger than *p* to be true, one plausibly didn't antecedently believe any stronger alternative to be false, so the falsity of each should be at-issue.

(127) ***Only* with desirability-based scales** (= (79)a)

q > p means: q is more desirable than p

p is low on < means: p isn't very desirable

a. Only p

e.g. Maybe Sam only has a degree from HARVARD, with alternatives Alt(a) = {Sam has a degree from Harvard, Sam has a degree from MIT}, and the ordering corresponding to Harvard < MIT.

≠> Sam has a degree from a place at least as good as Harvard

b. Relative to the common sense knowledge C which is shared across conversations, *only p* entails (123)(i)-(iii), and we evaluate the presuppositional status of each in turn.

c. Starting with (ii), as in (126)c, *p is low on <* is presupposed.

Turning to (i), we have

P(believe$_{t-1}$(p is true) | believe$_{t-1}$ C & acquire$_t$(only p))

= P(believe$_{t-1}$(p is true) | believe$_{t-1}$ C & **believe$_{t-1}$(p isn't very desirable)** & acquire$_t$(only p))

Here nothing clearly follows about the fact that p is antecedently believed. Similarly for (iii): no information is given about how expected or unexpected the more desirable alternatives initially are.

(128) ***Only* with entailment-based scales but without a 'low' component** (= (82)a)

q > p means: q is asymmetrically entails p

Component (123)(ii) is absent.

a. Only p

e.g. Our last customers had 7 kids. If the next ones only have 5, we'll know how to keep them busy.

≠> our next customers will have at least 5 kids

b. Relative to the knowledge C which is shared across conversations, *only p* entails (123)(i), (iii).

c. In the absence of information about expectedness, none of these entailments is likely to be antecedently believed when one learns that *only p* is true.

(129) ***Even* with entailment-based scales** (= (84)b)

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[72] A more realistic assumption would be that this value is close to 1 rather than equal to 1, but we aim for maximal simplicity at this point.

q < p means: p asymmetrically entails q

p is high on < means: p is unexpected

a. Even p

e.g. Ann says that this applicant is incompetent. Maybe he is even multiply incompetent, but in any event the boss will hire him.

$\not\Rightarrow$ he is incompetent

b. Relative to the common sense knowledge C which is shared across conversations, *even p* entails (124)(i)-(ii).

c. Starting with (ii), by (125),

$P(\text{believe}_{t-1}(\text{p is high on} <) \mid \text{believe}_{t-1} C \& \text{acquire}_t(\text{even p})) = 1$ so *p is high on* < is presupposed.

Turning to (i),

$P(\text{believe}_{t-1}(\text{p is true}) \mid \text{believe}_{t-1} C \& \text{acquire}_t(\text{even p}))$

$= P(\text{believe}_{t-1}(\text{p is true}) \mid \text{believe}_{t-1} C \& \mathbf{believe_{t-1}(p\ is\ unexpected)} \& \text{acquire}_t(\text{even p}))$

This probability should be low, so p is at-issue.

(130) *Even* **with desirability-based scales** (= (88)a)

q > p means: q is more desirable than p

p is high on < means: p is very desirable

a. Even p

e.g. I somewhat doubt that Ann Smith is an academic. But you know what? Assume that she is even a Distinguished Professor. I won't invite her to this particular workshop.

$\not\Rightarrow$ Ann Smith is an academic

b. Relative to the common sense knowledge C which is shared across conversations, *even p* entails (124)(i)-(ii).

c. Starting with (ii), by (125),

$P(\text{believe}_{t-1}(\text{p is high on} <) \mid \text{believe}_{t-1} C \& \text{acquire}_t (\text{even p})) = 1$ so *p is high on* < is presupposed.

Turning to (i),

$P(\text{believe}_{t-1}(\text{p is true}) \mid \text{believe}_{t-1} C \& \text{acquire}_t (\text{even p}))$

$= P(\text{believe}_{t-1}(\text{p is true}) \mid \text{believe}_{t-1} C \& \mathbf{believe_{t-1} (p\ is\ very\ desirable)} \& \text{acquire}_t (\text{even p}))$

This probability should not be particularly high, so p is not presupposed.

Definite descriptions and anaphoric triggers
Assumptions

(131) **Lexical entries for cases of referential failure**

a. [[the President]]^c = # unless there is exactly one president in c_w. If $\neq$ #, = the unique president in c_w.

b. [[she$_i$]]^c = # unless c(i) $\neq$ # and c(i) is female in c_w. If $\neq$ #, = c(i).

c. If i is a proposition-denoting variable, [[i^{possible}]]^c = # unless c(i) is possible in c_w. If $\neq$ #, [[i^{possible}]]^c = c(i).

(132) **Rule for *in addition***

[[in-addition]]^c(q)(p) = 1 iff p = 1 and q = 1 and p doesn't entail q

Examples

(133) **Expressions of type e** (= (91)a)

a. The president smokes.

b. Since verbs have a bivalent semantics and # isn't in the extension of any elementary predicate, *smokes* has the entailment $\lambda x\ x \neq \#$.

c. To determine whether this entailment is presupposed, we must assess relative to the common sense knowledge C which is shared across conversations the value of:

$P(\text{believe}_{t-1} x \neq \# \mid (\text{believe}_{t-1} C) \& (\text{acquire}_t (x \neq \# \text{ and } x \text{ smokes})))$

On the assumption that cases of referential failure are rare in cognitive life, this probability will be high and it will be presupposed that the argument of *smokes* does denote #.

(134) **In addition$_i$ / in addition to this$_i$** (= (94)a)

a. In addition$_i$, it's raining, as in:

It might be cold outside. If in addition (to this) it's raining, I won't go out.

analyzed as

a'. [[in-addition i^{possible}] it is raining]

b. Since # is not in the extension of any predicate, it is clear that

[[in-addition]]^c entails $\lambda q\ \lambda p\ p \neq \#$ and $q \neq \#$.

c. To determine whether this entailment is presupposed, we assess relative to the common sense

knowledge C which is shared across conversations the value of:

P(believe$_{t-1}$ p ≠ # and q ≠ # | (believe$_{t-1}$ C) & (acquire$_t$ (in-addition q p))

On the assumption that cases of referential failure are rare in cognitive life, this probability will be high and it will be presupposed that the proposition arguments do not denote #.

When applied to $[[i^{possible}]]^c$, this will yield a presupposition that c(i) denotes a proposition that counts as possible in c$_w$.

Appendix II
Exploitation

We start from an analysis in which P(believe$_{t-1}$ p | believe$_{t-1}$ c' & acquire$_t$ pp') ≥ a only yields a requirement that, relative to its local context, *p* has a probability ≥ a of being entailed by that context. Following the spirit of Bergen et al. 2016, we show that this can often be exploited to give rise to a near-certainty that *p* is entailed by its local context. In other words, if *stops smoking* comes with a requirement that there is probability ≥ a that *used to smoke* is locally entailed, strategic reasoning will lead to a near-certainty that *used to smoke* is in fact locally entailed.

We assume that there can be uncertainty about what is taken for granted in the conversation. At the initial state of the reasoning, then, the requirement is that listener L$_0$ should have probability ≥ a = (1-ε) of treating *used to smoke* as being presupposed, by way of the mechanisms we outlined above. But there is also a probability ε that L$_0$ treats *used to smoke* as being at-issue. The speaker S$_1$, for her part, is in the following situation. She could utter *pp'*, with a small risk of *p* being treated as at-issue. But if this is her goal, she could be explicit about it, for instance saying *Robin used to smoke and stopped,* i.e. *p and pp'*.[73] So there are two cases to consider depending on whether S$_1$ means for *p* to be treated as presupposed or as being at-issue. We will write as U$_1$(pp' | p at-issue) the expected utility for S$_1$ of an utterance of *pp'* on the assumption that she wants to treat *p* as being at-issue, and more generally U$_1$(utterance | intended meaning) will be the utility obtained by a certain utterance given a certain intended meaning. We will take utility to be 1 if the meaning is conveyed, 0 if it's not, and the cost of an expression E will be written as c(E). We consider each case in turn.

Case 1: S$_1$ wants *p* to be treated as at-issue

U$_1$(pp' | p at-issue)　　　　= (probability of communicative success * 1) - cost
　　　　　　　　　　　　　　= ε - c(pp')

U$_1$(p and pp' | p at-issue)　　= (probability of communicative success * 1) - cost
　　　　　　　　　　　　　　= 1 - c(p and pp')

S$_1$ being rational, S$_1$ will produce *p and pp'* just in case

U$_1$(p and pp' | p at-issue) > U$_1$(pp' | p at-issue)

or in other words just in case

1 - c(p and pp') > ε - c(pp'), i.e. 1 - ε > c(p and pp') - c(pp')

If we write δ for the cost difference between the expression *(p and pp')* and the expression *pp'* (i.e. δ = c(p and pp') - c(pp')), this condition will be satisfied whenever ε + δ < 1.

Case 2: S$_1$ wants *p* to be treated as presupposed

The equations are different when *p* is intended to be presupposed.

U$_1$(pp' | p presupposed)　　　　= (probability of communicative success * 1) - cost

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[73] See Beaver 2008 and Schlenker 2008b for discussion of cases in which one might not be able to be explicit in this way.

$$U_1(p \text{ and } pp' \mid p \text{ presupposed}) \quad \begin{aligned} &= (1\text{-}\varepsilon) \text{ - } c(pp') \\ &= (\text{probability of communicative success} * 1) \text{ - cost} \\ &= 0 \text{ - } c(pp') \\ &= \text{-}c(pp') \end{aligned}$$

If these are the only alternatives, S_1 can only produce pp' if she intends for p to be presupposed, since uttering *(p and pp')* would yield a certainty of miscommunication and (because of the cost) a negative utility. So to summarize:

(135) Behavior of S_1

In all cases, if S_1 intends p to be presupposed, S_1 utters pp'; in other words: P(pp' | p presupposed) = 1 (and thus P(p and pp' | p presupposed) = 0).

Whenever $\varepsilon + \delta < 1$, if S_1 intends p to be at-issue, S_1 utters *(p and pp')*: P(p and pp' | p at-issue) = 1 (and thus P(pp' | p at-issue) = 0).

Now the non-naive listener, L_1, reasons on the basis of S_1's utility maximization behavior, as summarized in (135). On the assumption that L_1 wants to recover the meaning intended by S_1, it is clear that this immediately leads to the conclusions in (136).[74]

(136) Behavior of L_1

in call cases, if S_1 utters *(p and pp')*, always treat p as presupposed

in case $\varepsilon + \delta < 1$: if S_1 utters pp', always treat p as presupposed

In other words, despite the presence of a small chance ε that p was not treated as presupposed by the naive listener, strategic reasoning leads to the conclusion that a more sophisticated listener will treat p as presupposed with probability 1.

Appendix III
Epistemic Preconditions vs. Counterfactual Stability

Schlenker 2018 sketches a triggering rule according to which *counterfactually stable local entailments are presupposed*. As stated in (107), the test asks that one consider a contextual entailment p of E, and that one assume, relative to the assumptions of the context, that E holds true. Then it assesses the counterfactual stability of the entailment p by asking whether, on the counterfactual assumption that E had not been the case, p would still have held, as stated in (137)a.

(137) Assume $C \models E \Rightarrow p$ (i.e. p is a contextual entailment of E). If $\rightarrow$ represents the counterfactual conditional, the test is whether:

$C, E \models (\text{not } E) \rightarrow p$

Yes: treat p as a presupposition.

No: do not treat p as a presupposition.

We will prove a very limited equivalence between a version of the 'counterfactual stability' idea and the present analysis based on epistemic preconditions. The key is to provide the non-standard semantics for conditionals in (138). It is a 'variably strict' conditional in the domain of worlds considered by a strict conditional is given by a belief state Bel_t, but is expanded to an earlier and weaker belief state if the antecedent of the conditional is inconsistent with Bel_t.

(138) **Semantics of** $\rightarrow$

We assume that information growth is monotonic, and thus that one believes at t+1 everything one believed at t, but not conversely, and that beliefs can be arbitrarily weakened if one is willing to go far enough in the past. We write as $\Rightarrow$ the material implication.

If w belongs to a belief state Bel_t, then for non-modal expressions F and G, $\text{Bel}_t, w \models F \rightarrow G$ has the

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[74] In greater detail: L_1 needs to determine the probability that S_1 intended p to be treated as at-issue or as presupposed. Using Bayes's rule,

P(p at-issue | pp') = [P(pp' | p at-issue)/P(pp')] * P(p at-issue) = 0 since P(pp' | p at-issue) = 0. Therefore P(p presupposed | pp') = 1. And in all cases, P(p at-issue | p and pp') = 1.

following truth conditions:[75]
(i) indicative case: if $Bel_t \not\models$ not F, Bel_t, w $\models$ if F, G iff $Bel_t \models$ F => G;
(ii) counterfactual case: if $Bel_t \models$ not F, and if Bel_{t-1} = the most recent belief state $Bel_{t'}$ such that $\mathbf{Bel_{t'} \not\models not}$ **F**, then
Bel_t, w $\models$ if F, G iff $Bel_{t-1} \models$ F => G.

It can now be observed that a version of the analysis with counterfactual stability is equivalent to a version of the analysis with epistemic preconditions.

(139) We write $Bel_t \models$ F for: for each w in Bel_t, Bel_t, w $\models$ F.
Using the notations of the main text, and on the assumption that C $\models$ E => p, the following two conditions are equivalent.

   a. Modified counterfactual stability
   if $believe_{t-1}$ C and $acquire_t$ **E**, $Bel_t \models$ (not E) $\rightarrow$ p

   b. Modified epistemic precondition
   $P(believe_{t-1}$ **p** | $believe_{t-1}$ C & $acquire_t$ **E**) = 1

Note that the conditions in (139)a imply $believe_{t-1}$ C & **E**, which connects the condition $Bel_t \models$ (not E) $\rightarrow$ p to the condition C, E $\models$ (not E) $\rightarrow$ p in (137).
        The proof is straightforward.

(i) To prove (a) => (b), assume Modified counterfactual stability, and assume $believe_{t-1}$ C and $acquire_t$ **E**. By (a), $Bel_t \models$ (not E) $\rightarrow$ p. Since $believe_t$ **E**, $Bel_t \models$ E and the conditional is counterfactual, so using (138)(ii) we get $\underline{Bel_{t-1} \models (not\ E) => p}$. Since $believe_{t-1}$ C and (by assumption) C $\models$ E => p, we also have that $\underline{Bel_{t-1} \models E => p}$. Taken together, the two underlined condition imply that $believe_{t-1}$ **p**. In other words, if $believe_{t-1}$ C and $acquire_t$ **E**, $believe_{t-1}$ **p**, or: $P(believe_{t-1}$ **p** | $believe_{t-1}$ C & $acquire_t$ **E**) = 1.

(ii) To prove (b) => (a), assume $P(believe_{t-1}$ **p** | $believe_{t-1}$ C & $acquire_t$ **E**) = 1 and $believe_{t-1}$ C and $acquire_t$ **E**; it immediately follows that $believe_{t-1}$ **p**. Since $Bel_t \models$ E, to evaluate $Bel_t \models$ (not E) $\rightarrow$ p we must apply the counterfactual rule in (138)(ii). Since $acquire_t$ **E**, Bel_{t-1} is the most recent belief state that doesn't entail *E*, the condition is that $Bel_{t-1} \models$ (not E) => p. It is fulfilled because $believe_{t-1}$ **p**, ie. $Bel_{t-1} \models$ p.[76]

Appendix IV
Further Problems

❑ *Time granularity*

As noted in discussions with U. Sauerland (p.c.), if times are too finely individuated, the present analysis will make incorrect predictions. Take of a helicopter classifier in ASL performing an upwards

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[75] Note that both cases can be unified under clause (ii) if 'closest earlier belief state' is replaced with: 'closest earlier or identical belief state'.

[76]   Without fully comparing the two frameworks, we note that the analysis based on counterfactual stability has one potential advantage over the one advocated in this piece, and one empirical drawback. The potential advantage is that judgments about the value of counterfactual statements might be easier to elicit than ones about the intuitive probability of certain conditions. For instance, for an example involving the verb *take off*, we could state the counterfactual stability test as follows:

(i) Suppose at 12:05 the company's helicopter was on the ground and took off. If this entire thing hadn't happened, would it still be the case that right before 12:05 the company's helicopter was on the ground?

A drawback of an approach based on counterfactual stability is that it probably makes incorrect predictions for the *prove* class. *Did Smith prove that Jones was the murderer?* does not presuppose that Jones was the murderer. But the test based on counterfactual stability might well make the wrong prediction in this case: on the assumption that Jones was the murderer and Smith proved it, if this entire thing hadn't happened, it is likely that Jones would still have been the murderer.

movement and thus representing a take-off (a normal one, with no pause, deviation, etc). The desirable presupposition is just that the helicopter is initially on the ground. Suppose information is obtained by direct perception, and that the take-off starts at 12:05 and ends at 12:09. If we take t = 12:00 and t+1 = 12:10, we get that upon learning by direct perception that the helicopter took off, one plausibly antecedently knew that it was initially on the ground. But if we take t = 12:08 and t+1 = 12:09, upon learning that the helicopter took off, one antecedently believed much more, namely that it was initially on the ground, had performed an upwards motion, was in the air, etc. Furthermore, an excessively time granularity will systematically yield this problem. This suggests that time increments in the discovery process should not be too fine-grained.

❑ *Maximize Presupposition*

According to *Maximize Presupposition* (e.g. Heim 1991, Sauerland 2003, 2008), *Sam believes that the earth is flat* is deviant because *Sam knows that the earth is flat* has the same at-issue component but a stronger presupposition. Since the present theory has not lexical presuppositions (except for definite descriptions and anaphoric expressions), the presupposition of *know* must be generated before it is compared to *believe*. On our 'official' theory, *know* lexical entails the truth of its complement, and the triggering rule can apply on the basis of this lexical entry together with common sense knowledge that is shared across conversations. This makes it possible to emulate the results of lexical accounts of presuppositions, and to adopt standard accounts of presupposition maximization.

In the more context-sensitive analysis sketched in Section 10.1, this emulation is harder to perform: in a context that guarantees that *x believes that p* entails that *p*, the (bivalent) contextual meaning of *x knows that p* and *x believes that p* will be hard to distinguish. One possible solution would be to adopt Anvari's principle of Logical Integrity (2018), which seeks to unify *Maximize Presupposition* with several other pragmatic principles. Logical Integrity specifies that *a clause S is unacceptable in local context c' if it has a logically non-weaker alternative S' which it contextually entails relative to c'*. Anvari shows that this derives *Maximize Presupposition*. His system assumes lexically triggered presuppositions, and a notion of 'logically non-weaker' alternative that is computed relative to purely logical knowledge. But we could seek to re-interpret it so that *S' is logically non-weaker than S* means that relative to the common sense knowledge C that is shared across conversations, *S' with the presuppositions it may trigger relative to C is non-weaker than S with the presuppositions it may trigger relative to C*. To illustrate, *Sam knows that the earth is flat* entails and in fact presupposes relative to C that *the earth is flat*. If C is sufficiently weak (not a trivial assumption), *Sam believes that the earth is flat* has no such entailment (one may fail to know that the earth is flat). Thus the *know*-sentence is stronger and thereby non-weaker than the *believe*-sentence, but relative to the local context of the conversation, the *believe*-sentence entails the *know*-sentence, hence a violation of Logical Integrity.

❑ *Surprise*

M. Mandelkern (p.c.) notes that *surprise* might be a counter-example to our analysis. *Is Sam surprised that it's raining?* presupposes that it's raining. But upon learning that *x is surprised that p*, one might plausibly not antecedently believe that p because whatever causes x to be surprised might cause one to be surprised as well. The challenge is to draw a distinction between *x is surprised that p* and *x demonstrates that p*: the fact that *demonstrate* comes the implication that *p* is non-trivial was crucial to our derivation of the absence of a factive presupposition in this case. Three solutions could be considered. (i) The simplest one is to refine the bivalent implications of *x demonstrates that p* vs. *x is surprised that p*: we could posit that in the case of *demonstrate*, the inference is that *p* was *generally* surprising, whereas for *surprise* it is surprising *for x*. The difference might explain why, upon learning that *x is surprised that p*, one typically antecedently knows that *p*. (ii) An alternative solution is to deny that *x is surprised that p* has a factive entailment, as one may say without contradiction: *Marie wrongly believes that Trump became President through a direct election, and she is surprised that he got a majority of the popular vote*. On this view, what gets presupposed is that *x believes that p*, rather than *p* itself. One still needs to explain why *upon learning that x is surprised that p, one typically antecedently knows that x believes that p*, but this case might be similar to *regret*, in the sense that beliefs are typically easier to infer that people's attitudes about these beliefs. In addition, one needs to explain why the presupposition *x believes that p* is often strengthened into a presupposition that *p* (this problem might already arise for *regret* and *want*, as alluded to in fn. 23). (iii) A third solution would

be to rely on a syntactic peculiarity: *surprise* allows for the structure *It surprises Sam that it is raining*. This might make it possible to analyze the construction in terms of a concealed description (partly in the spirit of Percus 1997), along the lines of: *The fact that is raining surprises Sam / Sam is surprised by the fact that it is raining*. If so, the definite description might be responsible for the factive presuppositions.

❑ *Verbs vs. modifiers*

Y. Sudo (p.c.) asks whether one doesn't need a distinction between modifiers and verbs, as the latter trigger presuppositions in cases in which the former don't, as in (140)-(141).

(140) a. Did Sam start to work here?   => Sam didn't work here before
      b. Is Sam a new employee here?   ≠> Sam didn't work here before

(141) a. Did Sam continue to be in pain?   => Sam was in pain before
      b. Was Sam in continuous pain?   ≠> Sam was in pain before

On closer inspection, however, (140)b wouldn't be expected to strongly project presuppositions anyway, possibly because restrictors usually don't (Chemla 2009); to our ear, (142) behaves much like (140)b.

(142) Is Sam an employee that started to work here?

A closer match for (140)a is (143); it seems to behave like *start* in triggering the inference that the addressee's father didn't use to enjoy Italian opera.

(143) Does your father newly enjoy Italian opera?

      Turning to (141)a,b, we note that their positive versions have very different bivalent meanings, as illustrated in (144). Since the bivalent meaning of (144)b does not entail that Sam was in pain before, we don't expect this to be a presupposition.

(144) a. This afternoon, Sam continued to be in pain. => this morning, Sam was in pain
      b. This afternoon, Sam was in continuous pain. ≠> this morning, Sam was in pain[77]

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[77] Two further open problems bear mentioning.

1. B. Spector (p.c.) notes that *x agrees with y that p* has a different presupposition from *x and y agree that p*: the former but not the latter presupposes that *y* is committed to *p*. We conjecture that *x agrees with y that p* and *x and y agree that p* have slightly different bivalent meanings, as argued for related cases by Strickland et al. 2014 (who found that *John exchanged books with Susan* yields an intentionality bias for *John*, compared to *John and Susan exchanged books*). One possibility is that *At 12:05, Sam agreed with Pat that p* is understood as: *At 12:05, Sam (intentionally) did something that led to agreement with Pat about p*. If so, this would come with an implication that Pat's belief that p held before, and upon learning of the entire proposition, one would typically know of Pat's earlier belief. *Contradict* arguably works in this way: *At 12:05, did Ann contradict Mary?* seems to us to presuppose that *before* 12:05 Mary said something, whereas we do not obtain this inference in: *At 12:05, did Ann and Mary contradict each other?* (It can be checked with standard triggers that reciprocals do project presuppositions: *At 12:05, did Ann and Mary stop insulting each other?* presupposes that right before 12:05 each was insulting the other.)

2. G. Chierchia (p.c.) asks whether the present analysis can explain why causatives, such as *Did Ann make Johnny eat?*, presuppose neither the causing event (Ann's action) nor the resulting event (Johnny's eating). Here it will help to adopt Lewis's 1973 counterfactual analysis of causation as in (i), and a simplified lexical analysis of *make* as in (ii).

(i) e causally depends on c iff (if c were to occur, e would occur) and (if c were not to occur, e would not occur).
(ii) Ann makes Johnny eat iff for some events c, e, Ann participates in c, Johnny participates in e, e is an eating, and **e causally depends on c**.

Suppose that in many of the cases (e.g. 60%) in which one learns that *Ann makes Johnny eat*, the relevant counterfactuals in (i) are known, e.g. one knows that, in view of the preceding facts, if Ann force-feeds Johnny (= c), he will eat (= e), and if he eats (= e), Ann force-feeds him (= c). In these 60% of the cases, upon learning that Anne makes Johnny eat, one would simultaneously learn that Ann acted and that Johnny ate, with the result that neither could be antecedently known. The reason for the dependency is that by learning about the cause c, the effect e follows; and by learning about e, on the assumption that if c hadn't occurred, e wouldn't have occurred,

Supplementary Materials
Raw ASL data

Raw ASL data can be downloaded at the following URL:

https://drive.google.com/file/d/1Xl-u_FizMm5S2G7CQAQYh9HpiQLtOylB/view?usp=sharing

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one can infer the occurrence of c. Thus if the relevant counterfactuals are known sufficiently often, neither the cause nor the effect can be presupposed. (We note that unlike *make/force/cause*, on some uses, *explain* presupposes its complement, hence a contrast between *Did the heat force/cause Pat to leave?* and *Does the heat explain that Pat left?*; we leave an explanation for future research.)

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